Historical Records And Current Status Of Fucales (Cystoseira and Sargassum spp.) In The Gulf of Naples

Thesis

Link(s) to article on publisher's website:
http://dx.doi.org/doi:10.21954/ou.ro.0000c256

Historical records and current status of Fucales (*Cystoseira* and *Sargassum* spp.) in the Gulf of Naples

A thesis submitted to the Open University of London for the degree of

Doctor of Philosophy

by

Daniele Grech

Laurea Specialistica in Biologia Marina

Stazione Zoologica Anton Dohrn, Naples, Italy

The Open University, London, United Kingdom

November, 2016

The thesis was made under the supervision of:

Maria Cristina Buia (Director of Studies)

Section of Integrative Marine Ecology

Stazione Zoologica Anton Dohrn

Villa Dohrn, Ischia-80077, Naples, Italy

Adriana Zingone (Internal Supervisor)

Section of Integrative Marine Ecology

Stazione Zoologica Anton Dohrn

Naples-80121, Italy

Francesco Paolo Patti (Internal Advisor)

Section of Integrative Marine Ecology

Stazione Zoologica Anton Dohrn

Villa Dohrn, Ischia-80077, Naples, Italy

Luisa Mangialajo (External Supervisor)

Laboratoire ECOMERS

Université de Nice-Sophia Antipolis

Parc Valrose 28, Avenue Valrose-06108 Nice, France

dedicated to

Alessandra

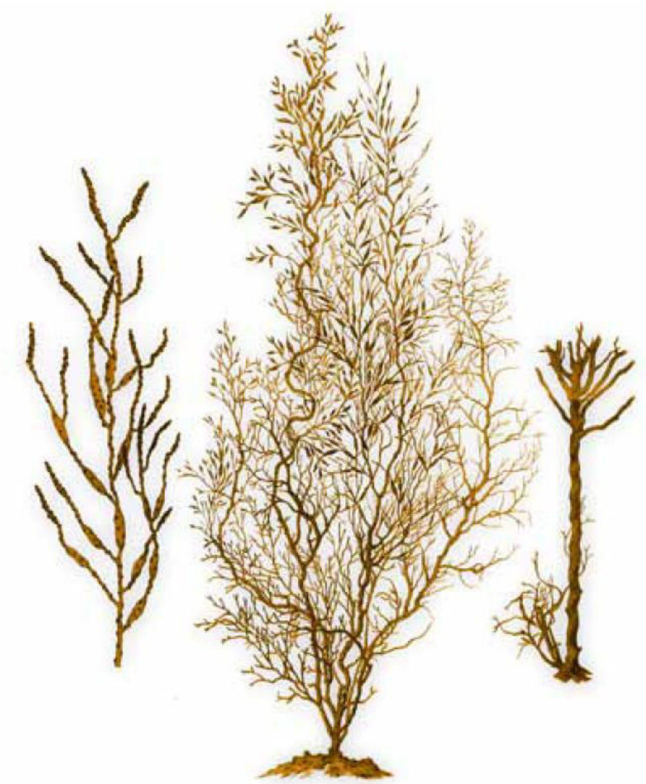
thank you for

existing !

'Here and there along the gulf, in springtime'

Angelo Mazza, on the occurrence of

Cystoseira hoppii, 1903 - Flora Marina del Golfo di Napoli



Abstract

Fucales are brown macroalgae that play a relevant structural and functional role in marine ecosystems but are experiencing a huge decline in many areas of the Mediterranean Sea. Despite the long tradition of phycological studies in the Gulf of Naples (Italy), a gap of knowledge on their dynamics and current status has been highlighted for the last 60 years in this area. This thesis aimed to provide an overview on long-term changes in the distribution ad abundance of *Cystoseira* spp. and *Sargassum* spp. along different sectors of the Gulf of Naples in the bathymetric range between 0 and 50 m depth.

Research was focused into three main objectives: 1) to assess the historical decline of Fucales the Gulf of Naples and their putative causes; 2) to map their current distribution; 3) to investigate the role of consumers in their loss. Results highlighted a decline of *Cystoseira* and *Sargassum* spp. mainly in the most urbanized areas of the gulf. Seven of the eighteen species recorded in the first half of the 20th century were no longer recorded; for other species the local decline could end up with their extinction if no action will be pursued for their conservation. A detailed georeferenced map (1:2,500) of Fucales has been elaborated for the shallow species; SCUBA surveys were performed for deep algae. Some human actions, such as coastal artificialization, can affect species richness and distribution in shallow sublittoral stands. Another mechanic pressure that can act on deep species is the intense fishing activities performed with fishing gears. Probably the interaction between the physic damage and the increase of water turbidity, related to a high eutrophication, can affect the vitality of deep species and their successful spread. The occurrence of patches of *Cystoseira,* among very dense and deep stands of *Posidonia oceanica* meadows in the oligotrophic waters around the island of Capri, seems to confirm this hypothesis. Another interesting result was obtained by a feeding choice experiment. The sea urchin *Paracentrotus lividus* fed indiscriminately on different macrophytes according to the equal choice behaviour between macrophytes offered alone or together, regardless of differences in total phenolic compounds content and C:N ratio. In conclusion, results infer that the improvement and maintenance of the environmental quality of the Gulf of Naples is a major issue not only for the welfare of the coastal ecosystems, but also for its social and economic spin off.

Acknowledgements

It was definitely an extraordinary adventure…..and what an adventure!

I would never have been able to conclude this important work without the help and support of many people close to me. They helped me physically, logistically and psychologically to complete this thesis.
There have been many difficulties, but also many joys and pleasant moments that I have shared throughout these three years of hard work with many people, all around the gulf.

First and foremost I want to thank my Director of Studies, Dr. Maria Cristina Buia, for selecting me to carry out this PhD; she believed in me and gave me the opportunity to get involved in this project, encouraging me in tough moments.
I also wish to thank all the members of the PhD supervision team: Dr. Adriana Zingone, Dr. Francesco Paolo Patti and Dr. Luisa Mangialajo and the final Examiners that through the comments substantially improved the quality of the manuscript.
My supervision team contributed a lot to my further growth at the end of these three year project giving me important feedback and suggestions.

I would like to acknowledge the funding and facilities provided by Stazione Zoologica Anton Dohrn. I am thankful to SZN-OU PhD committee and RITMARE project for allotting money to attend national and international conferences which helped me to stay connected with scientists worldwide.

I am really thankful to the SZN librarians and archivists, Pasqualina Fiorentino, Carmelina Scotti, Massimilano Maja, Andrea Travaglini and Claudia di Somma, they helped me enormously to find, manage and reconstruct a huge historical bibliographic baseline inside and outside the Stazione Zoologica archives and all the Herbaria curators who kindly answered to my queries.

I wish to thank Amit and Lucia for their suggestions in PhD life and discussions about our research work (‘we are in the same boat…’). I also wish to thank Carmen Arena from the Università Federico II di Napoli and her staff for the TCP analysis; Augusto Passarelli and Francesca Margiotta from SZN Naples, for the water nutrient and C:N analysis.
Thanks to all the staff of SZN of Villa Dohrn Ischia, the evergreen Benthic Ecology Group !

In particular to Maurizio Lorenti and Valerio Zupo for their scientific expertise (they helped in lab work, sample preparation, re-set-up tanks and helpful advice for feeding experiments) and extra-scientific fun; Beatrice Scipione for her huge skills as a researcher and her kindness; I cannot forget Anna Rando, Rosanna Messina and the awesome Francesco (‘Buongiornii per più giorniiiiiii’ or ‘Amìt c'ammadìtt’ cit.); without these people Villa Dohrn would not be the same place.

In particular, I want to sincerely thank the Captain Enzo Rando of the R/V Phoenicia for his assistance on surveys in snorkelling and scuba diving activities along Ischia; without his expertise, availability and problem solving attitude, to carry on my PhD activities would never have been possible. Hard task but at the same time doing it with extreme peacefulness, enjoying it!

Cristina, my boss, has been my buddy diver for most of the underwater surveys in Ischia and I want thank her hugely for this, too. Thanks a lot also to Bruno Iacono, diving officer SZN.

I want to thank the Regno di Nettuno, Gaiola, Punta Campanella and Baia MPA for the scientific authorizations and cooperation in carrying out surveys along the gulf. Thanks to all fishermen who have allowed me to interview them and to the diving centres in the gulf: Diving Agency, Ischia Diving, ANS Diving Ischia, Subaia, Punta Campanella diving center, Eurosub, Bikini diving, Amici degli Abyssi, Capri mare club. I hope I haven’t forgotten anyone....they have been extremely helpful!

Thanks to Prof. Bavestrello and Dr. Marzia Bo from University of Genoa for providing me with ROV videos of the Gulf of Naples and to Prof. Gianfranco Sartoni from the University of Florence for the beautiful and explanatory Cystoseira pictures with white background that he sent me to execute the draft and the final poster of the citizen science project 'Progetto Fucales'.

Thanks to Nicola Putzu, Claudio Vasapollo, Fabio Bulleri, Azzurra Bastari, Massimiliano Moraca, Lucia Porzio, Carlo Peris and Dario Pelli for tips and advice in GIS, statistics and PhD life; Enrique "Kike" Ballesteros for helping in the identification of doubtful samples and for revealing me the first secrets about the magic world of ¡ las Cystoseiras ! in Blanes four years ago.

Thanks to Mario Cormaci and Giovanni Furnari for their help in the interpretation of the complex taxonomic vicissitudes related to some species in the gulf. Thanks to Eva Cacabelos, she was very helpful clarifying me some details of food preference experiments, Iacopo Bertocci for his great help in data analysis and to Anna Santin for supporting me in those crowd burning days at the end of May, while I was handling hundred of things in the last season of my PhD.

Thanks a lot to Sabine Schwarzmaier for the interpretation of some German sentences in Funk's publications. During these three years, even if the group of students here in Ischia was small, there was a turnover of many people. Thank you all for creating such peaceful environment as possible as they were allowed (although sometimes it was very hard hehehe…): Amit 'compagno di ventura', Lucia, Martina, Sara, Nuria, Sanny, Antonia, Elena, Giulia, Anna, Alexia, Mirko, Emanuela, Shauna and the great Valerio (I mean the small one!).

Thanks to colleagues from Naples always ready to help and host me since I came from Ischia Island. You all have been a great help in any circumstances: Davide, Silvia, Giulia, Neri, Alberto, Chetan & Katerina, Francesco and all the other guys of the first year.

The work I did required vast organization, planning and rationalization of the efforts that had no equal. For the different sectors, there are yet many people I have to be grateful for kayaking and SCUBA diving surveys (and adventure related).

Carlo and Nicola for Procida, Peppe Renella of Diving Agency, for his friendship and his availability even though I became his nightmare….please let's go to 'Secca della Rana'! Thanks to Gennaro of Torregaveta (but how is it possible? We live in a modern era, we acquired scientific knowledge, you are neapolitan....nevertheless you are a supporter of Juventus ? However I must admit, with great astonishment, that you are 'nu bbbravo uaglion'); Ippolito Spina one of the funniest people I've ever met in the gulf, thanks for all the 'amazing adventures' and 'poetic pearls' at 6 a.m. on board of the M / N 'Thago'!

Thanks once more to the Gaiola MPA and C.S.I Gaiola for their kindness and for the involvement in the MEDPAN Project as well as their hospitality and helpfulness. In particular I want to thank Maurizio Simeone together with Paola, Oscar, Alberto, Daniela, Lino and all the remaining group of 'quei pazzi del conventino' that every day try to protect a piece of sea as it was their own life ! Never give up, guys !

Kayak Napoli and then Davide, Ciro, Armando and Guillaume for the C sector, they know what I mean!!!
Lega Navale of Castellammare of Stabia for landing and resting after a three days non-stop marathon.
Thanks again to AMP Punta Campanella, the director Antonino Miccio and his crew: Domenico Sgambati, Linda Testa, Nicola Guida and the magnificent group "Mare project" in action! And....what a pity that the Jeranto Bay is just outside the study area !

Thanks to the extraordinary availability of Mimì and Alba it was possible to achieve my final dream and objective: the conquer of the entire gulf !

Thanks to everyone involved in the citizen science project Progetto Fucales; the most extraordinary photographer family: Enrico, Maria Rosaria Gargiulo & sons, M.A.R.E in one simple word! Guido Villani, Massimiliano De Martino, Marco Gargiulo, Fabio Russo, Gabriella Luongo, Edoardo Ruspantini, Giampiero e Virgilio Liguori, Davide De Benedictis, Stefano Memoli, Fabio Masiello, Marco Bartolomucci and other anonymous photographers.
Thanks to Antonio Arcucci and Alessandro (Alias 'Trecciolino') for the 'unlucky' dives in Capri; despite of the wind, the rain and the state of the sea, they turned to be great ad fundamental dives!

I am indebted to my parents, grandparents and brother for supporting me, they helped me continuously to believe in my real passion: the sea. A feeling that you ‘watered’ between Sardinia and Tuscany sea life down to the cliffs to reach remote bays…thanks to all that, I was ready for this journey in the gulf.

I am grateful to you, Alessandra, partner of my life in work and in leisure: many good times and many difficulties at many km of distance during these years.
Thank you for spending your time to help me, despite the fact that you also were very busy, thanks for diving and snorkelling with me, discussing daily difficulties, thank you for believing in a future together despite many complications, thank you for having such smile and eyes (and everything else) that made me fall in love with you.

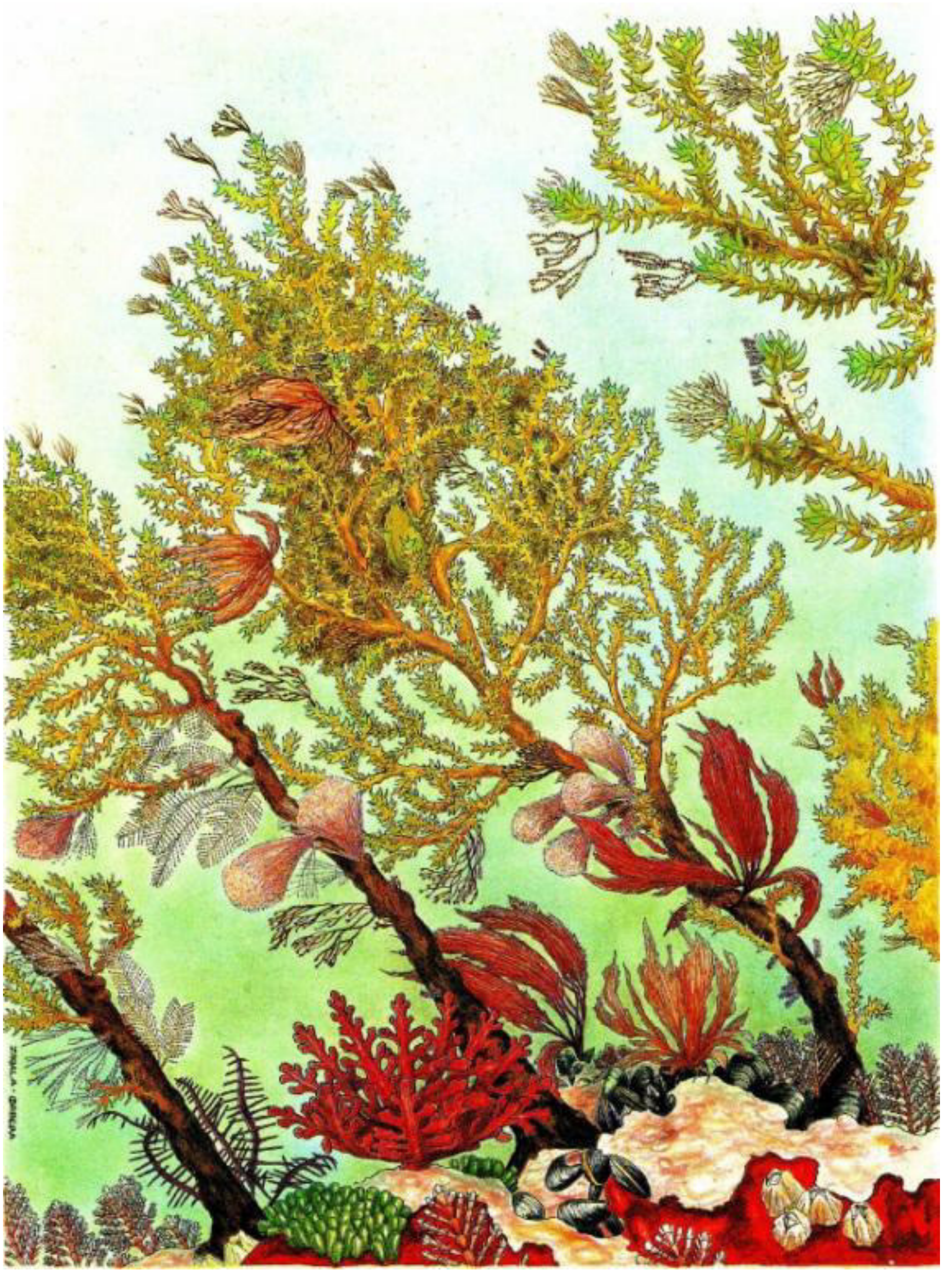
Now that I've finished my work, I cannot believe I really did it, but nothing would have been possible without
YOU ALL

…grazie !

Daniele

Table of content

1. General introduction



1.1 Introduction

The worldwide increase of human population and anthropic activities are leading to a huge deterioration of habitats with massive negative effects on biodiversity and ecosystem integrity. These pressures are mainly exerted on marine habitats, which support socio-economic and ecological goods and services for the whole planet. Among different species experiencing a declining trend, marine ecosystem engineers deserve special interest because they support many associated species, contributing to maintain high level of biodiversity, both structural and functional. The study on the occurrence of these species and their status is not only a conservation concern: it is a priority that must be achieved before their complete loss, in order to furnish a proper reference line for a long term assessment evidencing early warning signals leading to their unsustainability.

This thesis aims to provide an updated scenario of some peculiar ecosystem engineers, the brown macroalgae of the genera of *Cystoseira* and *Sargassum* present in the Gulf of Naples (Italy), an area historically inhabited by these species but currently suffering huge human pressures.

1.2 Worldwide decline of Fucales

We are currently almost 7.5 billion of people in our blue planet (Figure 1) but the number is expected to increase in the next thirty years as well as the current high number (60 %) of human population living in costal zones (Figure 2, Figure 3).

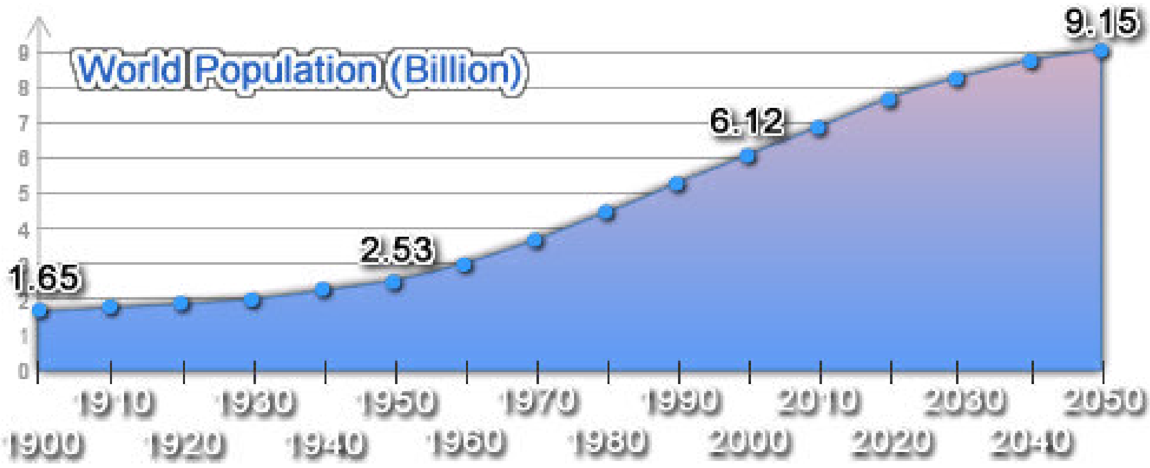


Figure 1: World population growth and near forecast for the future (http://www.i-nomad.net/2011/03/disturbing-chart-of-ever-increasing.html)

Figure 2 : Coastal population and shoreline degradation (Harrison & Pierce, 2001)

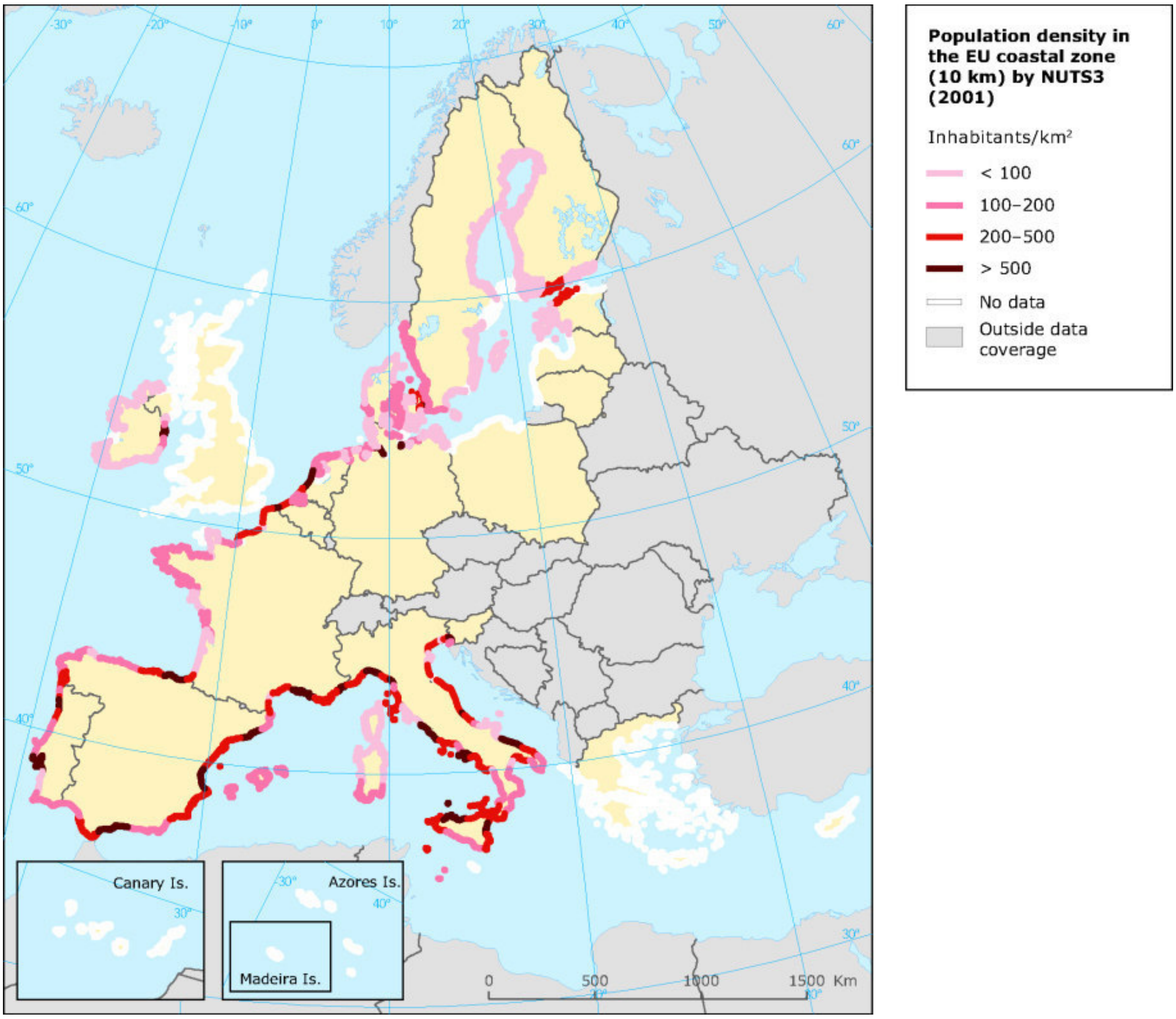


Figure 3: Population density along European coastal zones (EEA, 2009)

Anthropic pressures negatively affect marine environment causing different types of impacts (i.e. pollution, overfishing, oil spill, maritime traffic). The cumulative pressures affecting the Mediterranean Sea are summarized in Figure 4. Among impacts, habitat loss, resulting from the human expansion along land, coastline and sea bottom reclamation, is strictly correlated with the biodiversity depletion worldwide (Pimm & Raven, 2000) and it is directly linked with the increasing of human population density.

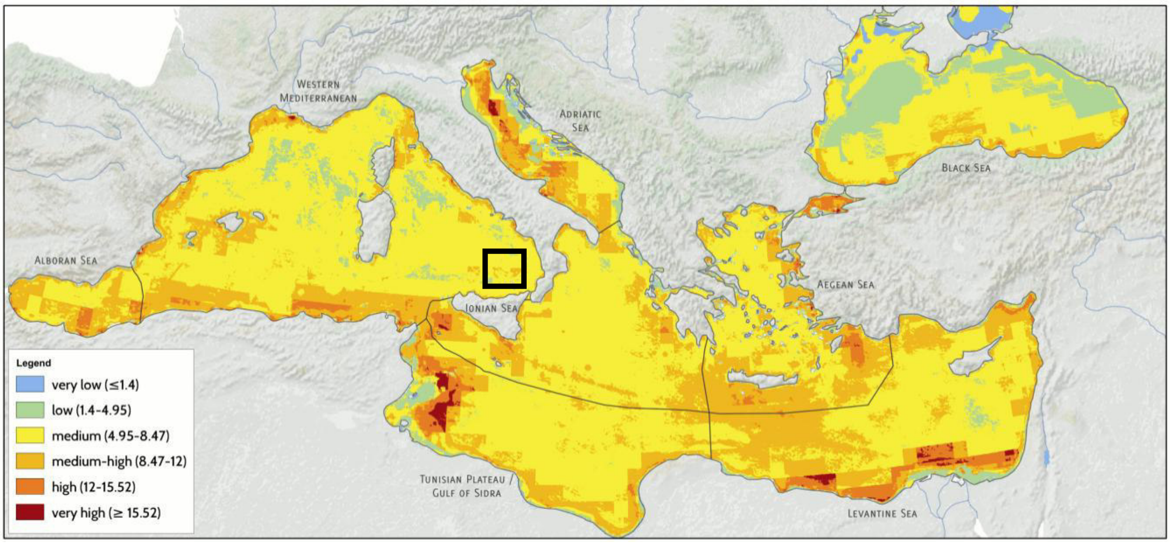


Figure 4: Cumulative pressures in the Mediterranean basin; in the frame the Gulf of Naples (from Micheli et al. 2005, modified).

Besides different species overwhelmed and threatened by human pressure ever increasing on coastlines (Millennium Ecosystem Assessment, 2005), the loss itself of a species has an intrinsic importance not only as taxonomic entities, but also as a valuable resource for many other species to which it provides shelter, refuge, and a substrate for feeding, reproduction, spawning and nursery. The valuable functional roles of these species in ecology are recognised by many authors with the well-known concepts of 'keystone species', 'canopy-forming species', 'habitat-forming species' and 'ecosystem engineers' (Menge et al., 1994; Jones et al., 1994; Jones et al., 1997). All these definitions focused on the importance of the functional role of one/few species for many others.

It is fairly evident that the widespread loss of these species can cause dramatic shifts in structure and function of ecological systems, with implications for global economy too. In fact, marine habitats are estimated to provide 10 trillion of euros of ecosystem goods and services per year corresponding to the 43 % of the global total (Costanza et al., 1997). If no effective action will be implemented, relevant habitats such as coral reefs, seagrass meadows and algal forests (that can contribute in different ways to the success of this economy) are going to collapse through huge cascading effects. In the framework of Marine Spatial Planning (MSP) and Integrated Coastal Management (ICM) it is of fundamental interest to know biology, ecology and distribution of these sensitive and threatened species, in order to properly calibrate and carry out adequate conservation and management effort.

Among canopy forming species, we include large brown algae belonging to the Fucales and Laminariales orders: they are suffering an intense decline worldwide.

In Table 1 an overview of the world decline of Fucales and Laminariales species is reported. Both orders are cited as they are responsible of the formation of sublittoral forests but the *Laminaria* and *Macrocystis* genera will not be taken into account in this dissertation.

Table 1: Phaeophyceae decline and evidenced cause of loss

Species	*Cause of loss*	*Region*	*References*
FUCALES			
Acrocarpia, Caulocystis, Cystophora, Scaberia, Scytothalia, Seirococcus	urbanization	Australia	Connel et al., 2008
Ascophyllum nodosum	harvesting, climate change , trampling	Atlantic Ocean	Airoldi & Beck, 2007; Bokn & Lein, 1978; Munda, 1974; Keser et al., 2005; Araujo et al., 2009, 2012; Birkett et al., 1998; Christie et al., 1998
Bifurcaria bifurcata	pollution industrial and domestic sewage, non-treated outfall	Europe Atlantic	Diez et al., 1999, 2009
Cystoseira spp.	habitat destruction, eutrophication and overgrazing,, 'minva' (very low tide for a long period of time, due to meteorological events), trampling, pollution, industrial and domestic sewage, non-treated outfall;	Mediterranean sea; Baltic Sea, Europe Atlantic, Okhamandal coast (India)	Arnoux & Bellan-Santini, 1963, 1964, 1972; Bellan-Santini & Desrosiers, 1977; Soltan et al., 2001, Boudouresque et al., 1990; Cecere et al., 1996, 2001; Celan et al. 1979; Clarisse, 1980, 1984; Cormaci & Furnari 1999; Cormaci et al., 2001; Desrosiers et al., 1982 and 1986; Devescovi &

			Ivesa, 2007; Diez et al., 1999, and 2009; Falace et al., 2010; Fraschetti et al., 2011; Giakoumi et al., 2012; Guidetti et al., 2003, Huvé, 1970; Kostenko et al., 2008; Langmead et al., 2009; Macic et al., 2010; Mangialajo et al., 2008; Milazzo et al., 2002; Milchakova, 2003; Minicheva, 1966; Munda, 1974, 1982, 1993, 2000; Rodriguez-Prieto, 1992; Rodríguez-Prieto & Polo 1996; Petranu, 1996; Sala et al., 2012; Sales et al., 2011; Sfriso et al. 1987; Soltan et al., 2001; Susini et al., 2007a,b; Susini, 2006; Templado, 2014; Tewari & Joshi, 1988; Thibaut et al., 2005, 2011, 2015a,b, 2016b; Tsiamis et al., 2013; Vasiliu & Muller, 1973; Zaitsev & Mamaev, 1997; Zaitsev, 2006; Verges et al., 2014.
Fucus spp.	Pollution, grazing, ice scouring, increased turbidity and decreased light levels, increased sedimentation, competition with filamentous algae, harvesting oil spill, coastal development and pollution, grazing	Atlantic Ocean, Europe, Finland Poland; Germany, Sweden, Denmark, Lithuania Baltic Sea Mediterranean	Kangas et al., 1982; Haahtela, 1984; Kangas & Hällfors, 1985; Plinski & Florczyk, 1984; Vogt & Schramm, 1991; Kautsky et al., 1986; Eriksson et al., 1998; Engkvist et al., 2000;, Middelboe et al 2000; Kangas et al., 1982; Messner & von Oertzen, 1991; Vogt & Schramm, 1991; Olenin & Klovaité, 1998; , Berger, 2004: Bokn & Lein, 1978; Munda, 1974; Fernandez & Niell, 1982; Nilsson et al., 2004; Airoldi & Beck, 2007; Rosemarin et al., 1986; Kautsky, 1992; Andersson & Kautsky, 1996; Malm et al., 1999; Engkvist et al., 2000 Waern, 1952; Haahtela, 1984; Kiirikki & Ruuskanen, 1996; Kautsky et al., 1986; Vogt & Schramm, 1991;Kiirikki, 1996; Schramm, 1996; Kangas et al., 1982; Worm et al., 1999, Birkett et al., 1998, Christie et al., 1998; Stekoll & L. Deysher,1996; Nilsson et al., 2004,1999;
Halidrys siliquosa	eutrophication, thermic anomalies, biological interactions	Sweden	Lundälv et al., 1986
Phyllospora comosa	sewage outfall	Australia	Coleman et al., 2008; Campbell et al., 2014

Sargassum spp.	channel excavations, limited water exchange, eutrophication; by land reclamation anthropogenic perturbations, over exploitation and climate change, land reclamation, urbanization	Mediterranean, Japan, Okhamandal coast India, Japan, Australia	Sfriso et al. 1987; Terawaki et al., 2003; Thibaut et al., 2005; 2015a, 2016a; Sfriso & La Rocca, 2005; Airoldi & Beck, 2007; Watanuki et al., 2010; Yu et al., 2012; Tewari & Joshi, 1988; Serisawa et al., 2004; Okuda et al., 2008; Connel et al., 2008; Phillips et al., 2011; Bianchi et al., 2014; Verges et al., 2014.
Scytothalia dorycarpa	marine heat waves	Australia	Connel et al., 2008; Smale & Wernberg, 2013;
Silvetia compressa S. fastigiata	urbanization	Southern California	Dawson, 1959, 1965; Widdowson, 1971; Murray & Littler. 1984; Whitaker et al., 2010; Munda, 1974

LAMINARIALES

Laminaria spp. Macrocystis spp.	eutrophication, coastal development and pollution, urbanization, grazing, seawater warming, land reclamation, harvesting with trawling, sedimentation.	Atlantic Ocean, Asturias (Spain), Iberian peninsula, Japan, Norway, Britain and Ireland, Australia	Hagen, 1995; Steneck et al., 2002; Fernandez & Niell, 1982; Serisawa et al., 2004; Connel et al., 2008; Raynbaud et al., 2013; Fernandez, 2011; Diez et al., 2012; Voerman et al., 2013;Tuya et al., 2012; Dayton et al., 1992,Okuda et al., 2008; Birkett et al., 1998b; Christie et al., 1998; Airoldi & Beck, 2007; Harrold & Reed, 1985; Reed et al., 1988, 1996; Kennelly et al., 1987; Dayton et al., 1984; Verges et al., 2014; Birkett et al., 1998b; Christie et al., 1998.

Human activities can alter chemical and physical characteristics of the fucoids environment: eutrophication, pollution (chemical and organic), altered sedimentation, altered salinity, land and sea reclamation and climatic changes are some of the most relevant threats acting with bottom-up control and directly modifying algal composition and diversity of the communities. However other human activities such as over-exploitation and introduction of novel and/or invasive species can alter the top-down control modifying populations of consumers, both predators and grazers. Such alterations of consumer populations often skew food webs in ecosystems, disrupting their functioning, and in extreme situations, causing ecosystem collapse (He & Silliman, 2016).

Researches on dynamics of vegetated Mediterranean rocky sublittoral communities have been focused on bottom-up controls (e.g. light, nutrient availability, temperature) (Ballesteros, 1991) (Figure 5) and on top-down control (e.g. predation) (McClanahan & Sala, 1997) (Figure 6) with two successional extremes (sea urchin barrens *vs*. fleshy algal communities) (Hereu et al., 2004).

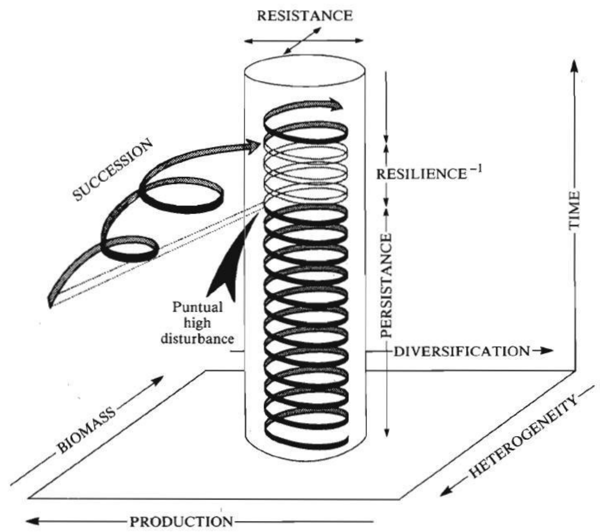


Figure 5: Three dimensional representation of the north-western Mediterranean phytobenthic communities dynamics over a long period of time (Ballesteros, 1991)

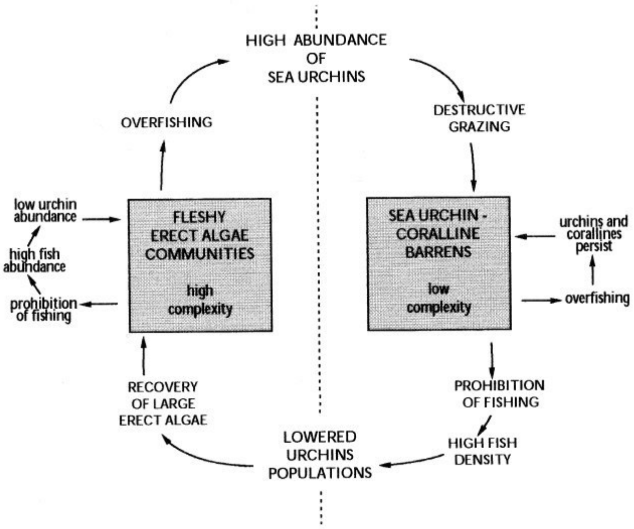


Figure 6: Model of dynamics of western Mediterranean rocky infralittoral algal assemblages (Sala et al., 1998)

However, studies of cumulative multiple stressor effects and interactions on one or more phases of the life cycle of fucoids (in particular those regarding egg and zygote dispersion and settlement) are necessary for improving coastal marine management, as the maintenance and conservation of shallow belts and deep forests of these large brown algae. These researches need to include baseline information and high resolution habitat maps.

1.3 Mediterranean Fucoids

In the Mediterranean Sea, the seagrass *Posidonia oceanica* and coralligenous assemblages are considered the first and second most important hotspot of biodiversity (Boudoresque, 2004), with an approximate number of associated species, about 800 and 1600, respectively (Boudoresque, 2004; Ballesteros, 2006).

Researches on the role of ecosystem engineer of fucoids (Figure 7) are relatively scant if compared to those on the previous two benthic systems even if *Cystoseira* and *Sargassum* species play a key role in the formation of a complex three dimensional habitat, widely recognized by many authors (Sauvageau, 1912; Funk, 1927; Feldmann, 1937, 1938, 1941; Molinier, 1960; Boudoresque, 1972). Some Fucales forests have been reported to have biomass values comparable or even higher respect to *Posidonia oceanica* (Robvieux, 2013). Furthermore, a not exhaustive and approximate account of species associated to Fucales forests resulted in more than 500 species but no overall data on their extension in the Mediterranean Sea is available until now.

Figure 7: Upper sublittoral and lower sublittoral *Cystoseira* (left) and *Sargassum* (right) spp. (the photo below at right is by Yiannis Issaris).

Cystoseira and *Sargassum* species constitute forests in the Mediterranean Sea that could be considered as miniaturized analogous of the Atlantic laminarian forests. The order Fucales widely occurs all along the world and it is represented by 9 families and 530 species (Guiry & Guiry, 2016). Many of these seaweeds form dense populations in the intertidal zone of temperate rocky shores with almost monospecific belts. Due to their relatively large size (from 20 cm to 1 m in length in very calm environmental conditions), they are considered habitat formers and ecosystem engineers (*sensu* Jones et al., 1994). The presence of three dimensional branched algae in the environment greatly modifies the colonized environment and promotes biological diversity (Ericksson et al., 2008; Mangialajo et al., 2008; Gianni et al., 2013). They are primary producers, exporting organic matter and oxygen producers for other ecosystems.

1.3.1 *Cystoseira* spp.

The *Cystoseira* genus was described in 1820 by the Swedish phycologist Carl Adolph Agardh; the name means ‘chain of vesicles’ (κυσις = vesicle and σειρα= chain) referring to the occurrence of air pockets on the thallus. At least 289 entities (species and intraspecific names) have been recognized but only 41 are currently taxonomically accepted (Guiry & Guiry, 2016).

Most of the species of this genus are neo-endemism, characterized by a speciation process which is still active today (Giaccone & Geraci, 1989); only *C. corniculata* and *C. barbata* are considered paleo-endemism of the Miocene. The Mediterranean Sea is therefore considered the hot-spot for *Cystoseira* species, where they reach the highest diversity (Cormaci et al., 2012). In fact, among the 41 species described worldwide, 30 of the 32 are present in the Mediterranean Sea and endemic of this basin, where they probably diverged after the Messinian salinity crisis about 6 million years ago and with an Atlantic ancestor (Hsu, 1982).

Giaccone & Bruni (1973) stressed about the importance of the high plasticity of this genus and the occurrence of a great number of ecotypes in different geographical zones and environmental conditions, according to the biogeographic phenomenon of vicariance. The possibility of hybridization between species evolved closely is indicative of a recent speciation event that may lead to vicariance in different areas of Mediterranean basin (Amico, 1995). Apart the endemic Mediterranean species, the remaining species extend their distribution into the northeast Atlantic Ocean.

Cystoseira species are considered some of the most important marine ecosystem-engineers (Molinier, 1960*;* Jones et al., 1994), forming extended stands comparable to land forests (Figure 7, 8). They increase three-dimensional complexity and spatial heterogeneity of rocky bottoms, providing substrate for many other algae, refuge, shelter and food for a lot of invertebrates ad vertebrates at different life history stages (Molinier, 1960; Ballesteros, 1990; Ballesteros et al., 1998; Benedetti-Cecchi et al., 2001; Chemello & Milazzo, 2002; Casu, 2006; Faucci & Boero, 2000; Bedini et al., 2011; Bulleri, et al., 2002; Riccato et al. 2008; Cheminee et al., 2013; Pitacco et al., 2014; Thiriet et al., 2016). Moreover, *Cystoseira* spp. associations showed the highest fish species diversity compared to other habitats (Orlando-Bonaca & Lipej, 2005). Juvenile forms of crustaceans, molluscs and polychaetes are dominant in this habitat (Kocatas et al., 2004; Gözler et al., 2010; Çulha et al., 2010; Pitacco et al., 2014). Among the most common macroscopic species we can cite the spider crab *Acanthonyx lunulatus* (very common in most of shallow stands), and many amphipod species that represent an important resource for the food web (Figure 8).

Mancuso et al. (2016) highlighted also the occurrence of bacteria associated with *C. compressa;* these bacteria can affect the health of this species, suggesting a possible role in its decline but further studies are needed in this still unexplored field of research.

Fucales are also important in terms of biomass. For example, maximum dry weight values recorded from May to November for *C. amentacea* can exceed 2 kg/m^2 (Bellan-Santini, 1972).

From the morphological point of view, these species are described as algae with a single axis or caespitose, up to 1 m high, attached to the substratum by a conical disc or by haptera (Gomez Garreta et al., 2001; Figure 9). The main axis is cylindrical (it is flattened in *C. baccata* only, a non mediterranean species), simple or branched; a greenish-blue iridescence is reported in some species.

Cystoseira species have a monogenetic diplontic life cycle, so the unique haploid stage is found in the gametes, which merges together forming a heavy zygote (Figure 10a). They are characterized by high reproductive potential, with abundant, large, heavy and easily sinking eggs and zygotes.

This reproductive strategy favours the formation of dense mono-specific assemblages, but limits the dispersal ability of the species, with important implications for their conservation and restoration.

Fertile receptacles are generally present in spring-early summer. Conceptacles are normally hermaphrodites, although in some species they may be unisexual at least during some period of the year. The algae are perennant and plurennial but with seasonal changes in shape and biomass during the year (Figure 10b, c, d).

Microscopic zygotes and juveniles, under optimal conditions of light, hydrodynamic and trophic conditions take up to several months to reach the macroscopic size, and the growth may be delayed under less favourable conditions (Gunnill, 1980; Schiel & Foster, 2006). The potential for delayed growth in early life stages has important implications for population replenishment, especially after a disturbance.

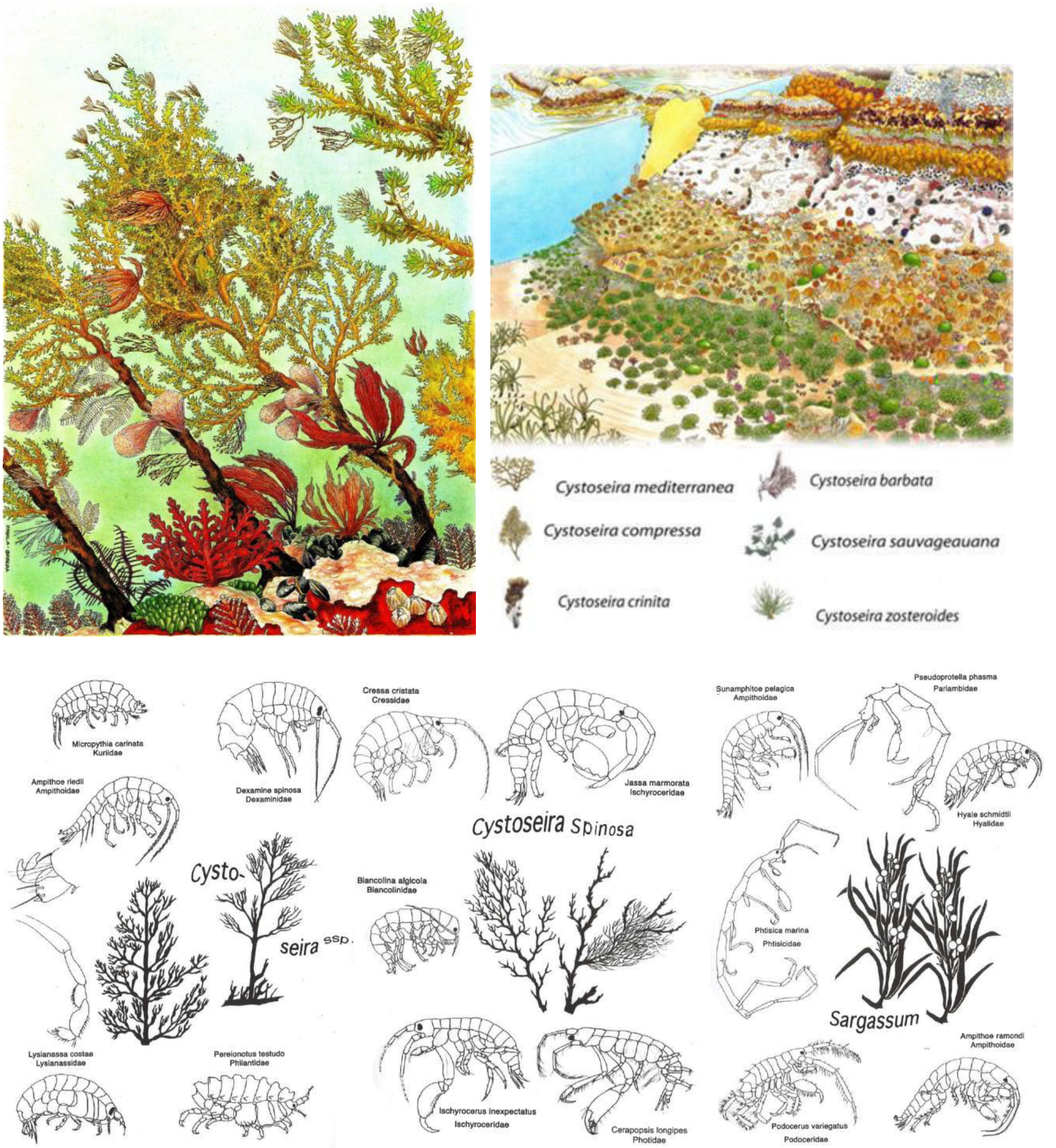


Figure 8: Three dimensional architecture of fucoids (Llimona et al., 1985) (a); zonation along a depth gradient (from Llimona et al., 1985, modified) (b) diversity of amphipods associated to different species (c) (from Costa et al., 2009, modified)

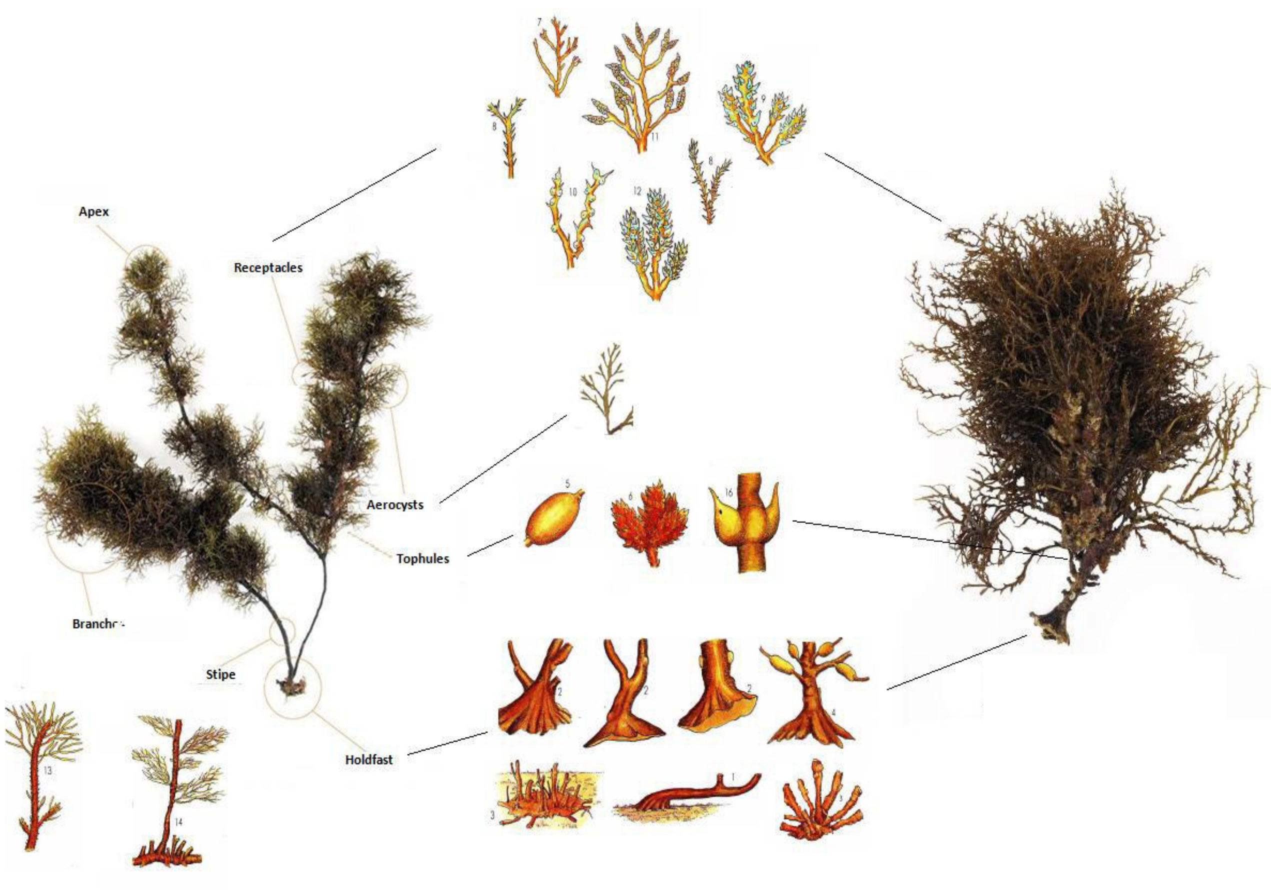


Figure 9 : Morphological features for their taxonomic identification (from Llimona et al., 1985 and Mannino & Mancuso 2009, modified).

This genus is characterized by a high diversity of secondary metabolites, both constitutive and wound activated. Verges et al., (2009) found that some species (*C. balearica* and *C. crinita*) are less grazed than others, probably due to the differential levels of terpenoid metabolites, which are considered absent from highly palatable species, such as *C. compressa* and *C. amentacea* (Amico, 1995).

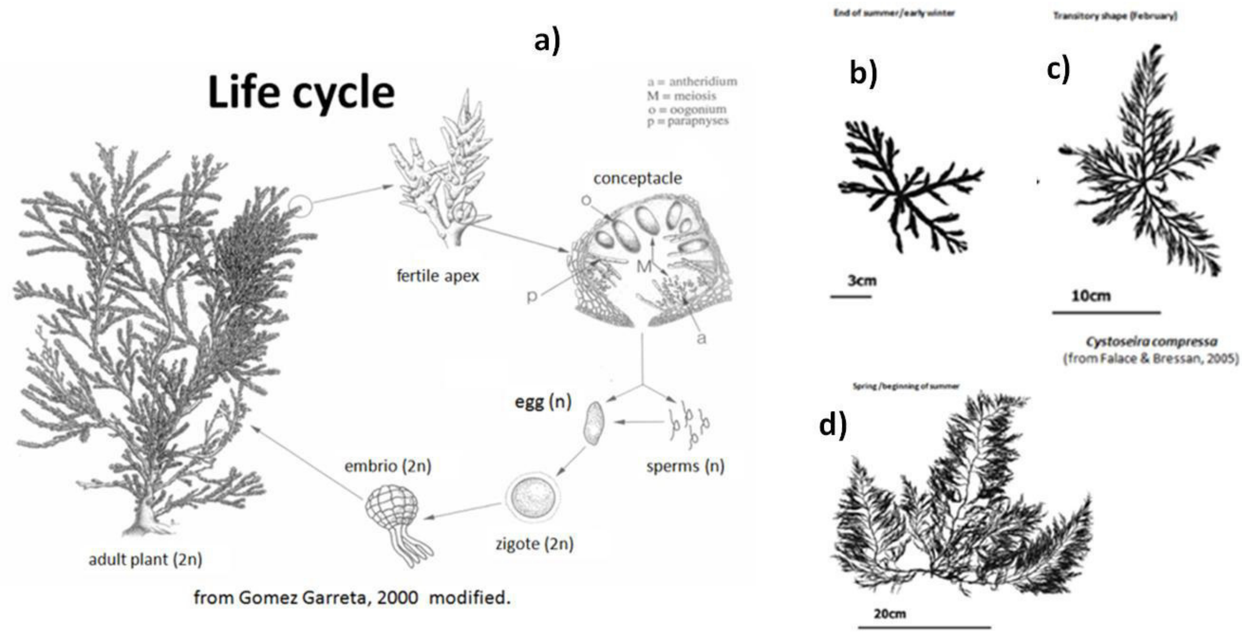


Figure 10: Life cycle of *Cystoseira* spp. (a, from Gomez Garreta et al., 2001, modified) and seasonal changes in shape and biomass between the end of summer (b) late winter (b) and spring (c) (from Falace and Bressan, 2005, modified)

Additional compounds are not constitutive but are produced as direct response to herbivore attack. In particular, Demirel et al., (2012) observed the highest concentration of total phenolic content in *Cystoseira spp.* in May, when the algal growth of the plant is the highest and therefore these species are more vulnerable.

Cystoseira spp. have k-strategy traits, are stenoecious and are differently sensitive to anthropogenic disturbances (Ballesteros et al., 2009). According to the different sensitivity to environmental variability, some of the shallowest species have been selected as biological indicators of environment quality in the frame of the Water Framework Directive (WFD, 2000/60/EC; Panayotidis et al., 1999; Buia et al. 2007; Pinedo et al., 2007). For this reason, they are useful tools to monitor the ecosystem health and hence the water quality (Arevalo et al., 2007; Ballesteros et al., 2007; Panayotidis et al., 2004; Asnaghi et al., 2009; Nikolic et al., 2013; Pinedo et al., 2007; Mangialajo et al., 2007). Pinedo et al., (2015) pointed out that *C. mediterranea* seems to be adapted to extremely low dissolved nitrates in seawater, being unable to resist to levels higher than 20 µmol/l of N.

In the last decades, the species of this group are experiencing substantial decline and progressive disappearance in various areas of the Mediterranean basin (Aysel et al., 1990; Cormaci & Furnari, 1999; Panayotidis et al., 1999; Thibaut et al., 2005, 2015a,b). This problem has been reported especially for the species thriving in the belt of upper infralittoral zone and in rock-pools, probably because they are easily monitored and because the coastal fringe is the most threatened. Among human pressures responsible for such decline, the increasing coastline urbanization, which destroys natural habitats and changes environmental characteristics (substrate, hydro-dynamism, loads of sediments, nutrients and chemical pollutants), is the most important stressor which could cause the regression of this algal group (Panayotidis et al., 2004). Loss of subtidal *Cystoseira* has also been ascribed to the outbreak of herbivores (Verlaque, 1984; Thibaut et al., 2005). Other potential threats could be agriculture, mussels farming and the sampling effort caused by scientific research, this latter in some cases underestimated up to now.

Even for deep stands the trend is critical, despite much less information is available: an almost nil recruitment after 10 years has been reported in some Spanish regions for some species (Ballesteros et al., 2009). This result highlights the vulnerability of deep species, usually characterized by very slow growth rates (i.e. the mean growth rate of the main axis of *C. zosteroides* is about 0.5 cm/year) (Ballesteros et al., 2009). For all these reasons, some of them such as *C. amentacea*, C. *mediterranea*, C. *sedoides*, C. *spinosa* and C. *zosteroides* have been considered protected species and listed in the European Conventions (Barcelona Convention 1976, 1995; Bern Convention 1979; Council of Europe 1979) but without true protection actions.

1.3.2 Sargassum spp.

Sargassum genus is represented by perennial (more rarely annual), large canopy-forming macro-algae. It is widespread and widely known genus because of its massive free-floating growth in the Sargasso Sea. This genus includes 353 accepted taxa with a great morphological variability, extensive geographic and depth distribution (from shallow to deep waters on reefs of temperate and tropical oceans). The origin of the name is not certain: it could derive from the Latin 'Salicastrum', a wild vine found in willow-thickets (*Salix* sp.) or it could derive from the Portuguese name 'sargaço', for the resemblance with the terrestrial sargaça rockrose (*Helianthemum* spp.) (Sumayaa & Kavitha, 2015).

Despite the high number of species worldwide, in the Mediterranean Sea there are only 8 native species (plus the introduced *S. muticum*) and all are benthic forms. They are considered large canopy-forming species providing shelter, food and nursery for a wide range of associated species (Thibaut et al., 2016a). They can reach 10-200 cm in length. The plants are attached to the substratum by a basal disc; the main axis is usually cylindrical, foliaceus branches have a midrib with smoot or toothed margins and aerocystis are sub-spherical or ovoid, pedicellate, sometimes apiculate.

Plants are monoecious or dioecious and, in the formers, receptacles and conceptacles are unisexual or hermaphrodite. Receptacles are axillary, generally branched, cylindrical or compressed, smoot, rugged or with spines, often on a sterile pedicel, grouped in more complex reproductive structures (Figure 11). The aerocystis allows the standing position and the dispersion far from the mother plant (Figure 12). This genus is taxonomically complex because of its great phenological and ecological variability (Gomez-Garreta et al., 2001).

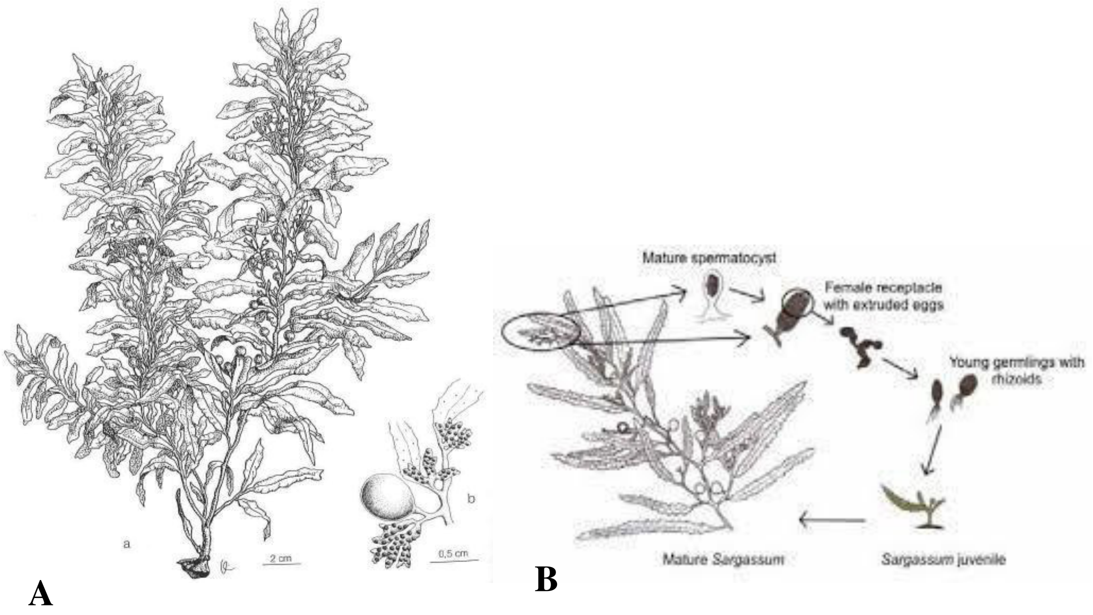


Figure 11: Receptacles and diplontic life cycle of *Sargassum* spp. (A, from Gomez-Garreta et al., 2001; B, http://seagrant.umaine.edu/files/SargassumManual_070914.pdf)

Most of the studies on the decline of fucoids have been focused on *Cystoseira,* and *Sargassum* status has been poorly considered. In the survey along almost 3000 km of North-Western Mediterranean coasts, Thibaut et al. (2016a) reported that several species were reported in the past, but now *S. vulgare* seems to be the most common. The increase in water turbidity, trawling and fishing nets are probably responsible for the regression of the deep populations of *S. hornschuchii* and *S. acinarium*. On the opposite, overgrazing by sea urchins and salema fish (*Sarpa salpa*), and coastal development are probably responsible for the decline of shallow (between few and 15-20 m of depth) populations. Despite these results, Mediterranean species of this genus (such as *S. acinarium* and *S. hornschuchii*) are surprisingly still lacking of any proper protection status, and are not included in the IUCN Red List.

Figure 12: Detached specimen of *Sargassum vulgare* at Torregaveta (Naples) drifted by current and surrounded by plastic and organic garbage, after an impressive meteorological event followed by intense raining.

1.3.3 Current knowledge on these species in the Mediterranean basin

In the Figure 13 the theoretical zonation of the most cited species of *Cystoseira* and *Sargassum* in the literature for the Mediterranean Sea according to Cormaci & Furnari (2012) is reported.

Unfortunately the current knowledge on the fucoids distribution in our basin is not homogeneous and most of the data regards mainly shallow species.

Along the Spanish coasts, the most recent records of upper sublittoral fringe are referred to Ballesteros et al. (2007) and Mariani et al. (2014). Ballesteros et al. (2007) performed an index (CARLIT, CARtography of LITtoral rocky-shore communities) based on the different sensitivity of *Cystoseira* species in order to evaluate the ecological status of water bodies and Mariani et al. (2014) implemented a Geographic Information System (GIS) based mapping of littoral habitats. In the frame of these researches, they mapped the distribution of the upper sublittoral zone. A bionomic cartography of the subtidal populations has been drawn for Montgri (Spain) (Hereu et al., 2010). It is worth to note that from the regions of Catalunya and Columbretes (Spain), Port Cros and Scandola (France) the knowledge on the growth dynamics and community structures of the deep *Cystoseira* species has been achieved (Ballesteros et al., 1998, 2009; Capdevila et al., 2015, 2016).

One of the most studied area in the NW Mediterranean is represented by the French coast (Alberes, French Riviera, Provence and Corsica) thanks to the long phycological tradition of this country and to the several historical herbaria still preserved (see Thibaut et al., 2015a and references therein). The recent comparison of historical data with those obtained in the 2007-2013 campaign highlighted that in this area the decline is real but not conspicuous; however probably 5 species have to be considered locally extinct and others as functionally extinct.

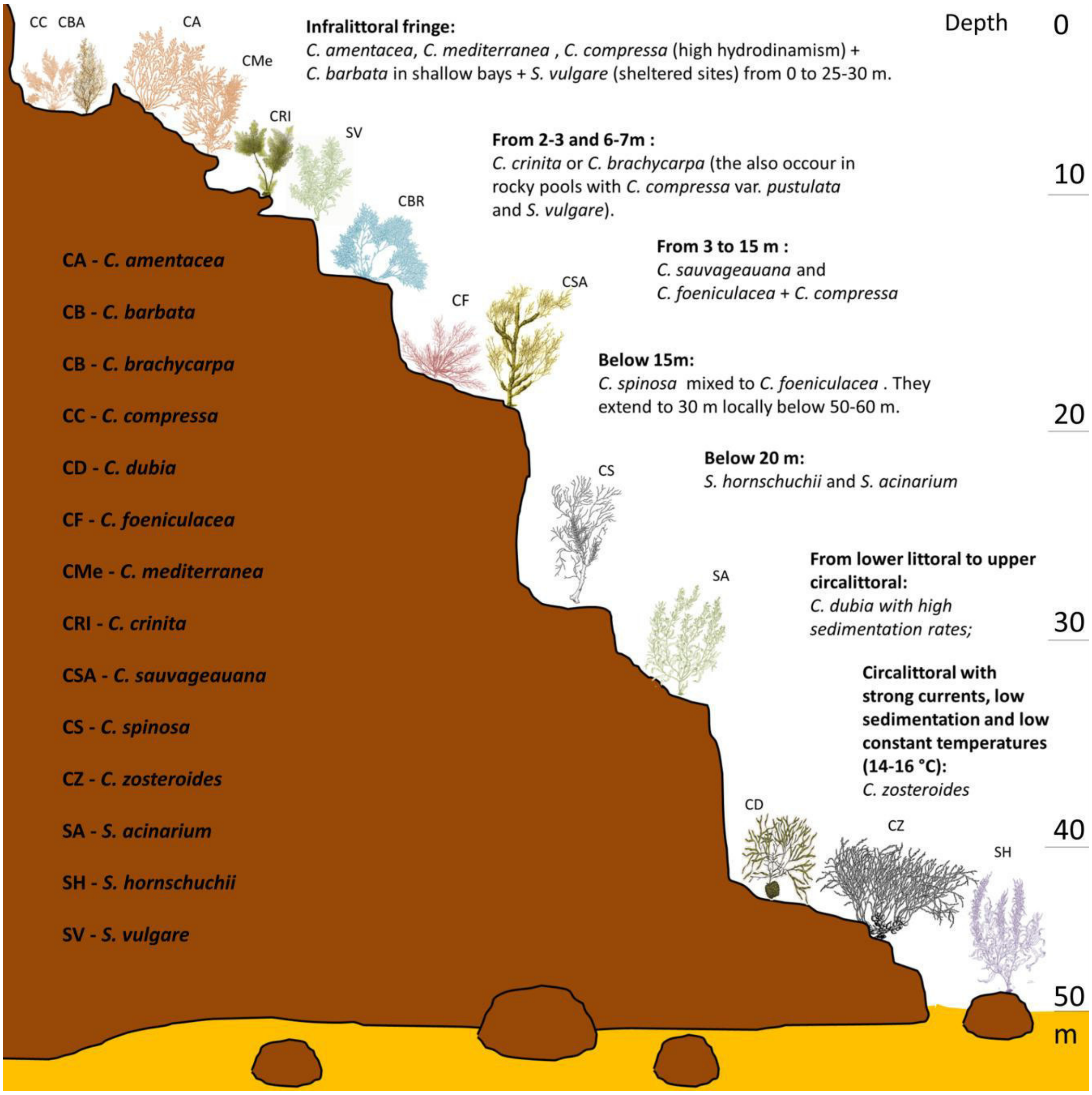


Figure 13: Fucales zonation scheme in Mediterranean Sea

As concerns the East Mediterranean, recent data for the Greek coasts are mainly related to the application of environmental quality indexes, according to the Water Framework Directive (WFD, 2000; Orfanidis et al., 2011; Giakoumi et al., 2012; Nikolic et al., 2013). In addition deep species never recorded in the past were currently monitored (Tsiamis et al., 2016).

Along North-East Adriatic countries (Slovenia and Croatia) no differences in the number of fucoids between current and historical data were found, even if a previous disappearance of *Cystoseira* and *Sargassum* stands was observed (Ercegovic, 1952; Turk & Vukovic, 1994; Orlando-Bonaca et al., 2008, Orlando-Bonaca & Mavric, 2014; Antolic et al., 2010; Ivesa et al., 2016, Bulleri et al., 2016).

As concerns the Italian coasts, the algal assemblages of rocky shores have been studied since long time, but data on their temporal dynamics are few and not contemporaneous. Along the Adriatic coasts Falace et al., (2010) highlighted a reduction both in richness and abundance for *Cystoseira* and *Sargassum* spp. and in the last decade also for the endemic *Fucus virsoides* that was in the past widespread in the intertidal zones (Rindi & Battelli, 2005; Battelli, 2016). Recent observations on the benthic algal flora of the area of Ancona (Central Adriatic Sea) seem to confirm the decline of *Cystoseira* spp. (Falace et al. 2010; Rindi et al., 2016).

Similar decreasing trends are occurring along the coasts of the Tyrrhenian (Benedetti Cecchi et al., 2001; Pardi et al., 2000) and Ligurian Sea (Mangialajo et al., 2008, 2012). As concerns middle and south Adriatic sea, a decline in fucoids stands and richness has been recorded by several authors since 2000 (Falace et al., 2010 and references therein; Fraschetti et al., 2012). Cormaci and Furnari (2012) recorded *C. squarrosa* along the coasts of Sardinia; it represents the first record of this species from the NW Mediterranean Sea after De Notaris's description in 1841. Even if many reports of *Cystoseira* are available for this island as well as for others (Sales et al., 2012), they are only spots and based on these data it is not possible to detect any change in their distribution. The first maps are those performed for the MPA Capo Carbonara and Tavolara-Punta Coda Cavallo (Ferrigno et al., 2014; Gianni & Mangialajo, 2016).

Finally, another area of the basin in which historical data go back to 19th century is the Gulf of Naples. A first attempt to measure historical changes in fucoids diversity (Buia et al., 2013a) has suggested a dramatic decrease in the distribution of *Cystoseira* in the upper sub littoral zones and at the same time has highlighted the lack of information on their up to date extension and the lack of data on deep species. In addition, in the frame of researches conducted on the effect of acidification, some results (Porzio et al., 2011; Kumar, 2015) seem to testify that in particular pH conditions Fucales, as well as other fleshy macroalgae, have the potential to overcame the negative effects of a change in the chemical composition of the sea water and sustain themselves in the future acidified ocean.

Among threats to marine belts and forests responsible of their decline, a relevant role has been attributed to the herbivory pressure. Species feeding on *Cystoseira* and *Sargassum* are mostly sea urchins and salema fish (*Sarpa salpa*) even if few other species can be considered.

Sea urchins are reported to completely remove dense population of erect macroalgae when they reach high density (from 7 to 20 individuals per square meter) with a 'bulldozing effect' and causing barren grounds (Verlaque, 1984; Orlando-Bonaca & Mavric, 2014).

In the last 25 years, *Sarpa salpa* (a Sparidae fish with a very low economic value, Figure 14) has attracted research interest because of its role as macro-grazer (Verlaque, 1984; Velimirov, 1984; Havelange et al., 1997; Jadot et al., 2000, 2002). According to Verges et al. (2009), these species are able to selectively graze different *Cystoseira* species. It is possible that the overfishing of large top predators lead to cascading effects in the food web, Unfortunately no information on historical change in abundance of salema fish are available but these fishes actually have no predators after their recruitment period (Valls et al., 2012; Prato et al., 2013) and recent studies proved that salemas grazing can highly affect *Cystoseira* forests, decreasing the biomass of more

Figure 14: Unusual selling of salema fish (*Sarpa salpa*) in Naples, Porta Nolana fish market

than 80% and the reproductive potential of more than 97 % (Gianni F. pers. comm.).

Other organisms have been reported to play a role interfering with the normal life cycle of these brown algae; they are gastropods belonging to the genus *Patella* (Benedetti-Cecchi et al, 2001). Probably they feed on the microscopic propagules of algae, limiting their spread and settlement in highly grazed habitats.

Mussels (*Mytilus galloprovincialis*) and introduced algal species (*Caulerpa cylindracea*, *Asparagopsis* spp., *Acrothamnion preissi* and *Womersleyella setacea*) can interact with Fucales recruitment. The first two species can be competitors for the space, in particular conditions of nutrient enrichment. The last two are likely to have a negative effect on *Cystoseira* as sediment traps (their turf-like structure traps a layer of sediment that prevents the attachment of the zygotes to the substratum).

Alien consumer species can affect fucoid distribution. The tropical herbivorous rabbit fishes *Siganus* spp. already make up a substantial proportion of fish abundance in some areas (between 5% and 45%; Harmelin-Vivien et al., 2005) and they are advancing westward, from Linosa (Italy; Azzurro & Andaloro, 2004) to the French Mediterranean coasts (Daniel et al., 2009). *Percnon gibbesi* a strictly herbivorous species, a characteristic not shared with any other large-sized infralittoral Mediterranean crab (Puccio et al., 2006). It is an Atlantic introduced species with an exuberant progress in our basin (Deudero et al., 2005); it is possible that this species could actively graze zygotes and propagules of the shallow fringe of Fucales where there is no competition with other Mediterranean crabs, such as *Pachygrapsus marmoratus* and *Eriphia verrucosa* that have a slightly different bathymetric habitat distribution.

The consumption by grazers seems to depend on the different palatability of the food item. The species belonging to the Fucales order, account for over a third of chemical compounds known among Phaeophyceae taxa; i.e. in *Cystoseir*a genus more than 100 chemical structures have been reported (Amico, 1995; Blunt et al., 2005) with different and interesting properties and activities (de Los Reyes et al. 2013; Sellimi et al. 2014; Mhadhebi et al. 2014). Usually, these highly diversified secondary metabolites play relevant ecological roles as protection against microbial infection, metal ion chelation and UV radiation, as well as antibiotic and antimycotic action. Moreover, other non-constitutive metabolites can be produced in response to an herbivore attack (wound activated compounds) (Maibam et al., 2014).

Cystoseira and *Sargassum* spp. are probably experiencing a sad common fate. In many areas the effect of different and combined threats resulted in their replacement by other morpho-functional algal species, with a progressive decreasing of the habitat structure and function of algal morphology and biomass. Dictyotales and Sphacelariales are generally among the first to colonize empty space followed by little and filamentous ephemeral algae, as some articulated corallines; the last step is the barren ground. The result is the erosion of biodiversity and the homogenisation of habitats with a decrease in three dimensional fractal heterogeneity, biodiversity, shelter and biomass (Figure 15).

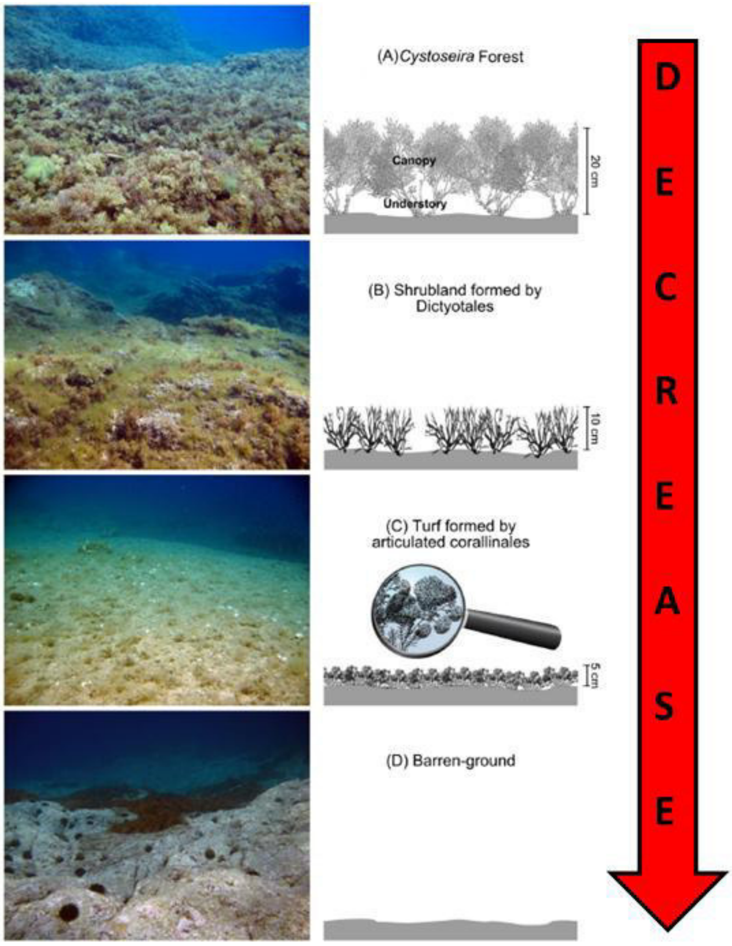


Figure 15: Consequences of Fucales loss and the resulting habitat shift (from Thriet et al., 2016, modified)

Few signals of Fucales recovery after decline have been observed both in Mediterranean Sea (Munda, 2000; Navarro et al., 2011, Fraschetti et al., 2012) and in Atlantic Ocean (Diez et al., 2009, Araujo et al., 2012) but the fate are strictly related to the control and management of the stressors that drove the loss. Recent meta-analyses (Strain et al., 2014), dealing on roles of stressors involved in the global loss of canopy-forming to mat-forming algae, showed that nutrient enrichment in particular interacts synergistically with a variety of other stressors, amplifying the negative effects on the decline of canopy-forming species (Strain et al., 2014) (Figure 16).

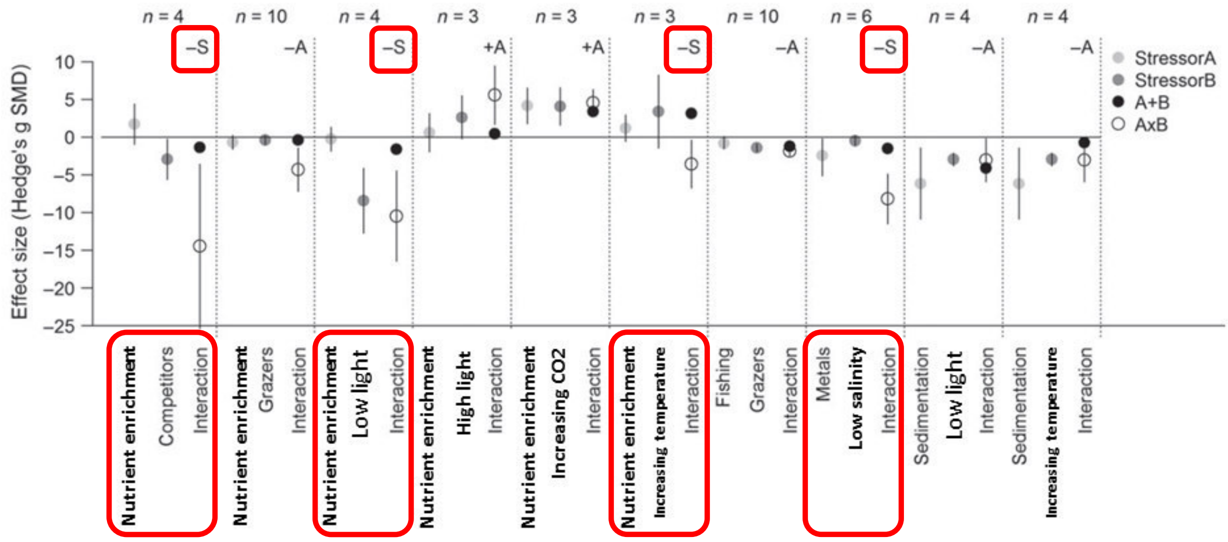


Figure 16: Results of meta-analysis on the effects of local anthropogenic stressors combined with other stressors on the growth of canopy forming algae (Stressor A=first listed stressor, Stressor B=second listed stressor; A+B=predicted effect of the interaction, AXB=actual effect of the interaction; –S =a negative synergistic effect; +S= a positive synergistic effect; -A=an additive negative effect; +A= a positive additive effects; from Strain et al., 2014, modified)

However, a meta-analysis focused on the effect of different stressors on Mediterranean Fucales was impossible to perform at the current state, due to paucity of studies related in literature. Further investigations to fill this lack of knowledge in future are needed.

Global stressors are not manageable locally, but have local impacts and may indirectly affect local stressors. Many stressors are threats for macro-algal diversity (at population and community levels), with huge impacts on coastal ecosystems. Some stressors may have direct and indirect impacts (e.g., habitat modifications can alter hydrodynamic conditions leading to an increased sedimentation, climate change can increase grazing pressure) (Mineur et al., 2015) (Figure 17).

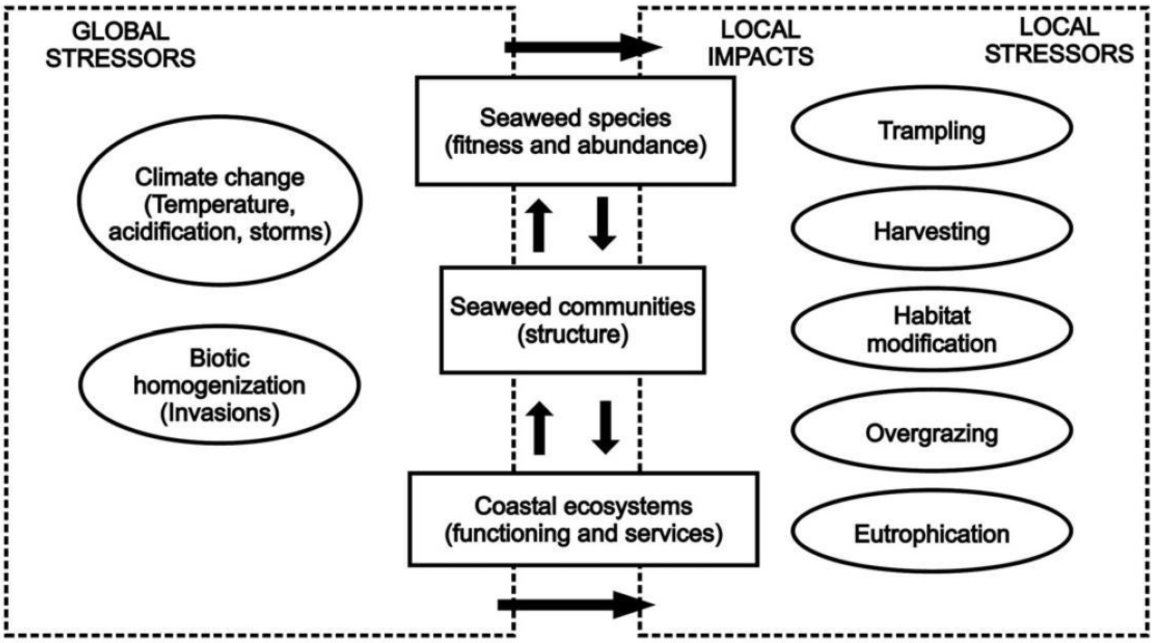


Figure 17: Global and local stressors affecting seaweeds (Mineur et al., 2015).

Strain et al. (2015) and Mineur et al. (2015) concluded that the management of nutrient enrichment would greatly increase the resilience of fucoid algae to climatic stressors, in particular to the increasing temperature.

Moreover, management and control actions on local stressors are undertaken differently in the different countries of the Mediterranean Sea and without a central and common 'Mediterranean legislation', despite many supra-national initiatives (Marine Spatial Planning, Marine Strategy Framework Directive, Integrated Coastal Zone Management).

1.4 Research aims and objectives

One of the main issues when dealing with fucalean species is the lack of current data, along with the lack of updated local information that can be a powerful evidence for decline detection and a useful tool for coastal management policy of conservation and restoration. Despite the decline process has been in place for a long time and well documented in many regions, the global awareness on that issue has actually increased only in recent years, with a shared interest among many researchers and a convergence into integrated research projects. Especially for deep species, detailed information is absent for most of the Mediterranean basin, with some exceptions (Thibaut et al., 2005; Ballesteros et al., 1998; Capdevila et al., 2016). Therefore, a proper assessment of their current status is missing.

This means also that a reference point for the assessment of historical changes for current and future research is still lacking in many regions. The risk to lose Mediterranean shallow belts and deep forests (with their related ecosystem good and services) before having the complete awareness of their existence and before developing proper conservation strategies is high.

A preliminary work conducted in the Gulf of Naples by Buia et al. (2013a) highlighted a decline in the richness of shallow species in the Gulf of Naples in the time period 19th-21st century and the urgent need to map their distribution in order to define their current status, detect the main local stressors and manage their conservation.

The main questions addressed in the present PhD project were:

Has the Fucales diversity changed in time in the Gulf of Naples? If yes, is the decline comparable between shallow and deep stands?

- Which are the current local stressors in the gulf? For which of them is possible to detect historical changes?
- Are there any relationships between pressures and impacts? Can we relate the decline/persistence of some species to some local putative stressors?

Different approaches were followed in this study: revision of the literature, survey of vouchers held in the SZN herbaria, queries to other Italian herbarium curators and citizens in the framework of a citizen science project, field surveys, mapping, field and lab experiments and chemical analysis.

The thesis has been divided into the following chapters with specific objectives:

Chapter 1. General introduction

Chapter 2. Identification of pressures and their impacts on vegetated coastal systems in the Gulf of Naples

Chapter 3. Historical changes of Fucales in the Gulf of Naples

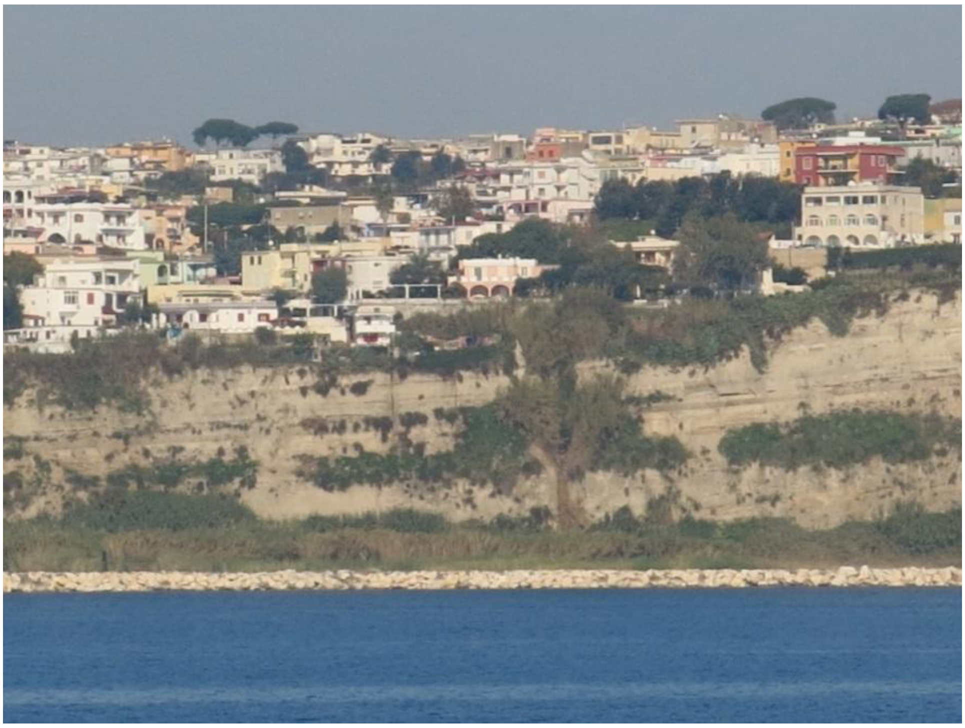
Chapter 4. Current distribution of Fucales in the Gulf of Naples and an evaluation of putative causes of decline

Chapter 5. A quantitative assessment of *Cystoseira* populations around the island of Ischia: a baseline to detect long term changes in their dynamics

Chapter 6. Top-down pressures

Chapter 7. General conclusions discussions and future directions

2. Identification of pressures and their impacts on vegetated coastal systems in the Gulf of Naples



2.1 Introduction

The increase of human population and activity worldwide is leading to a huge deterioration of coastal habitats with massive impacts on marine biodiversity and ecosystems. Historical and current pressures from multiple uses and stressors have threated the Mediterranean basin that has been defined as a sea 'under siege' (Lejeusne et al., 2010; The Mermex group: Durrieu de Madron et al., 2011). Micheli et al. (2013) elaborated a map of the widespread stressors and more than 50% of the Mediterranean basin resulted subject to a medium cumulative impact. When the basin has been analysed by ecoregions, the western Mediterranean recorded the lowest average cumulative impact although local areas of high impact exist. The identification of local scale pressures and impacts is fundamental for the implementation of a successful Marine Spatial Planning.

Besides its natural peculiarities, the region of Campania and the Gulf of Naples in particular, is subject to an intense anthropic pressure, determining a strong impact on the marine ecosystem. Along its coastline, human activities range from dense urban settlements to industrial areas located on the coast and intense maritime traffic. Moreover, the land runoff of polluted rivers can influence the physical, chemical and biological quality of the coastal waters. At the same time, the area is also an internationally renowned touristic location, not only for its historical and environmental attractions, but also for bathing and leisure activities from spring through fall. Consequently, the maintenance and improvement of the environmental quality of the region is a major issue not only for the welfare of the entire ecosystem, but also for social and economic reasons.

Among the most threatened habitats, those formed by benthic habitat former plants are of great interest. In the last decades, the species of this group are experiencing substantial decline and progressive disappearance in various areas of the Mediterranean basin (Aysel et al., 1990; Cormaci & Furnari, 1999; Panayiotis et al., 1999; Thibaut et al., 2005, 2015a,b; 2016a; Chapter 1 of this thesis). This problem has been reported especially for those species settled in shallow waters. Among human pressures responsible for such decline, the increasing coastline urbanization, which destroys natural habitats and changes environmental characteristics (nature of the substrate, hydro-dynamism, load of sediments, nutrients and chemical pollutants), seems to be the most important stressor (Airoldi & Beck, 2007). Loss of subtidal *Cystoseira* has also been ascribed to the outbreak of herbivores (Verlaque, 1984; Thibaut et al., 2005). Other potential threats could be maritime traffic, overfishing, mussels farming and agriculture (Thibaut et al., 2005).

The aim of this chapter was to make a review on the main characteristics of the Gulf of Naples describing its benthic vegetated systems and discussing the most important pressures and impacts affecting them. Scientific outputs present in literature have been evaluated and, when it was possible, some gaps were filled by new analysis.

2.2 General features of the Gulf of Naples

2.2.1 Geographical, geological and oceanographic aspects

The Gulf of Naples (Campania region) is located in the south western coasts of Italy in the central Mediterranean Sea (Figure 18). It is delimited on the north by Monte di Procida and on the south by Punta Campanella and it includes the islands of Ischia, Procida, Vivara and Capri (De Maio et al., 1979; Uttieri et al., 2011). It is 870 km² wide and 250 km long with an average depth of 170 m (Carrada et al., 1980). The seabed topography is very complex with two main submarine canyons (Magnaghi and Dohrn) at more than 800 m depth and a continental shelf extending between 2.5 and 20 km (Figure 19).

The gulf originated from two extensional events occurred in Pleistocene: the first one shaped the formation of a depression that is parallel to the Piana Campana along NE-SE direction, the second one set up on a NE-SO fault system, generating the current Gulf of Naples and many asymmetric structures such as the semi-graben, charactering all the Campanian margin. Of great interest is the anti-Apennine fault that from the Dohrn canyon extends to Banco di Fuori. This fault separates the east sector from the west one, respectively composed by sedimentary and volcanic units, related to Phlegrean fields and Ischia and Procida (Fusi et al., 1991).

The seafloor has an abrupt change between north and south side. The northern sector has irregular ground and it is etched by canyons and banks (mainly remains of volcanic structures) of great ecological interest. The southern side is mainly composed by fine sediments (mud) sloping very gently below to 200 metres and with the unique relevant rocky bank of ‘Banco di Santa Croce’.

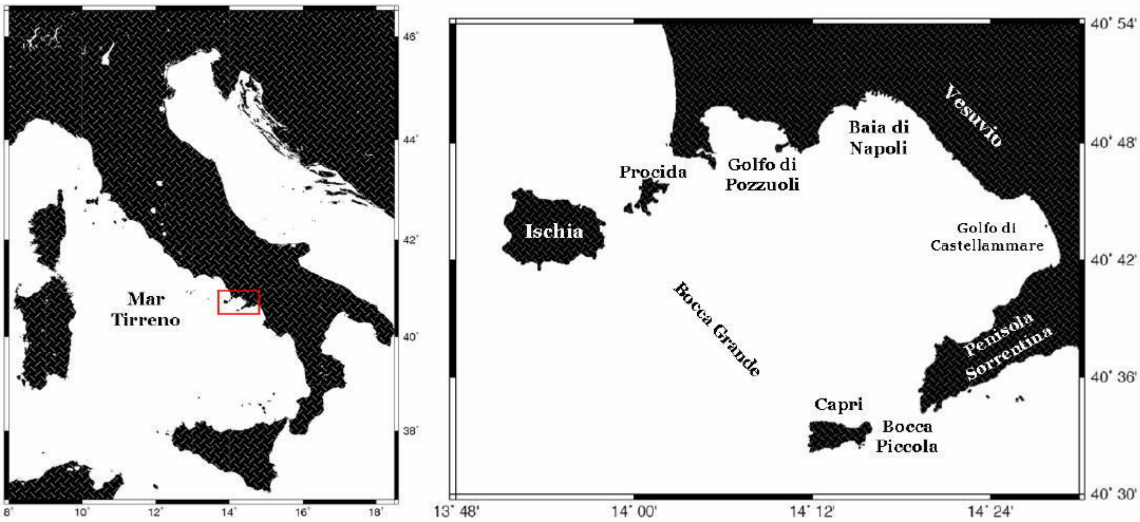


Figure 18: Localization of the study area (Menna, 2007)

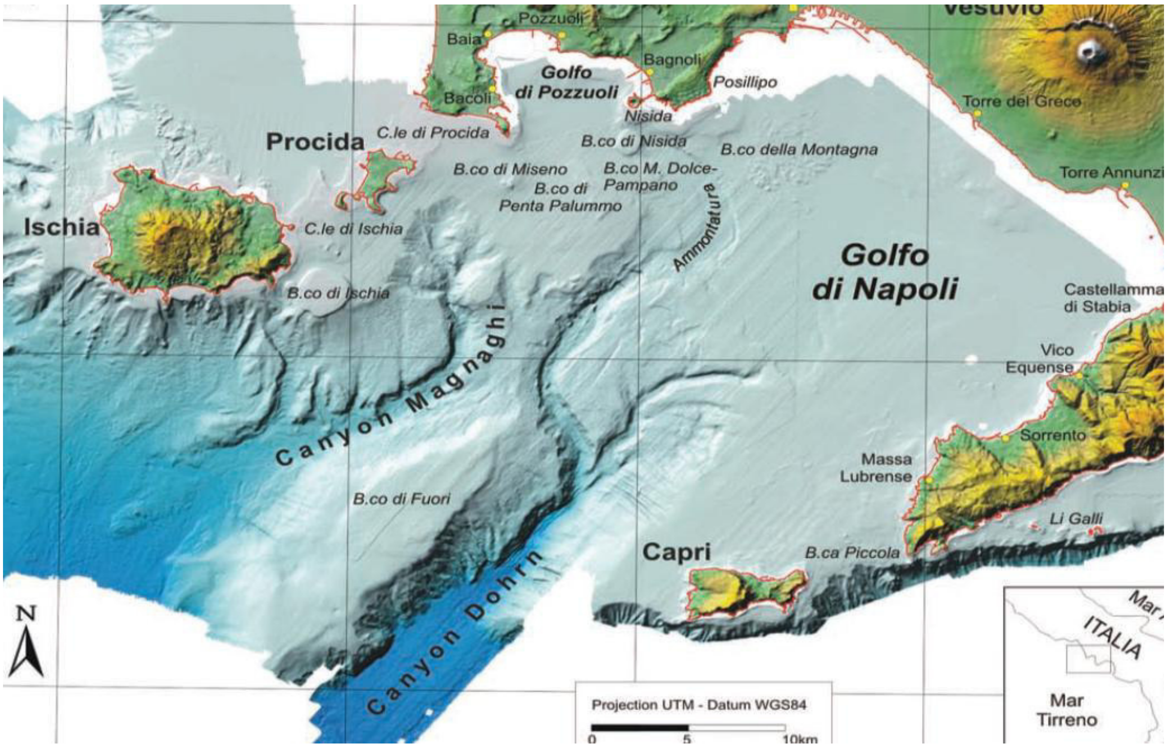


Figure 19: Topography of the bottom (D’Argenio et al., 2004)

The Sorrento peninsula and Capri Island have limestone geology (neritic and platform limestone, turbiditicous) of Cretaceus and Jurassic period, while the north west side of the gulf has volcanic origin (lavas, pyroclastites) of Quaternarian cycle (Figure 20).

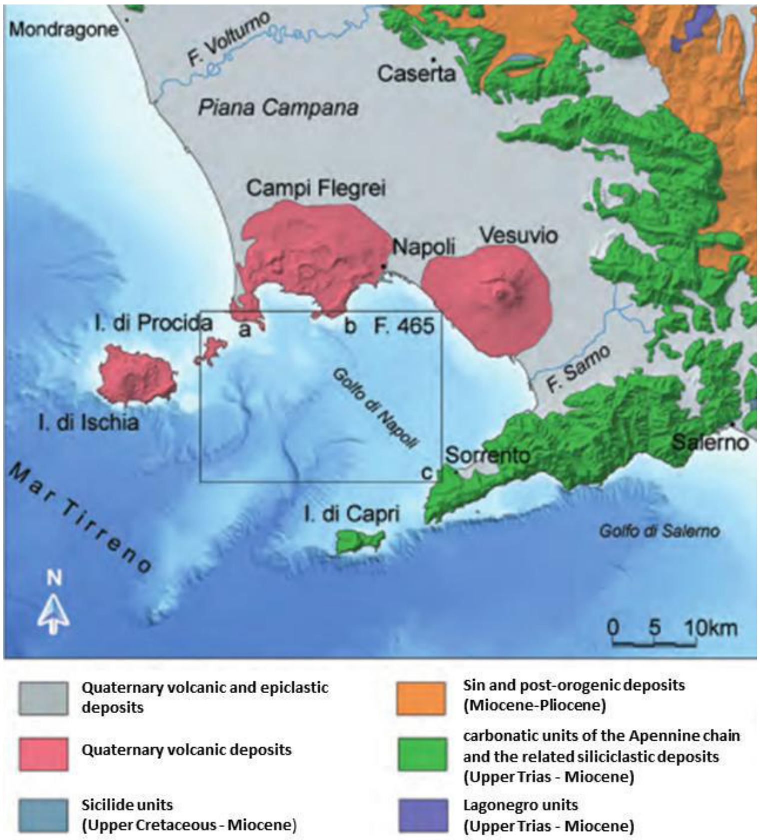


Figure 20: Geology of study area (from http://www.isprambiente.gov.it/Media/carg/campania.html, modified)

Ocean circulation is strongly influenced by local factors, such as wind intensity and direction. During winter and summer dominant winds come from NE and SW, in spring and autumn from NNE and SSW (Menna et al. 2007) (Figure 21).

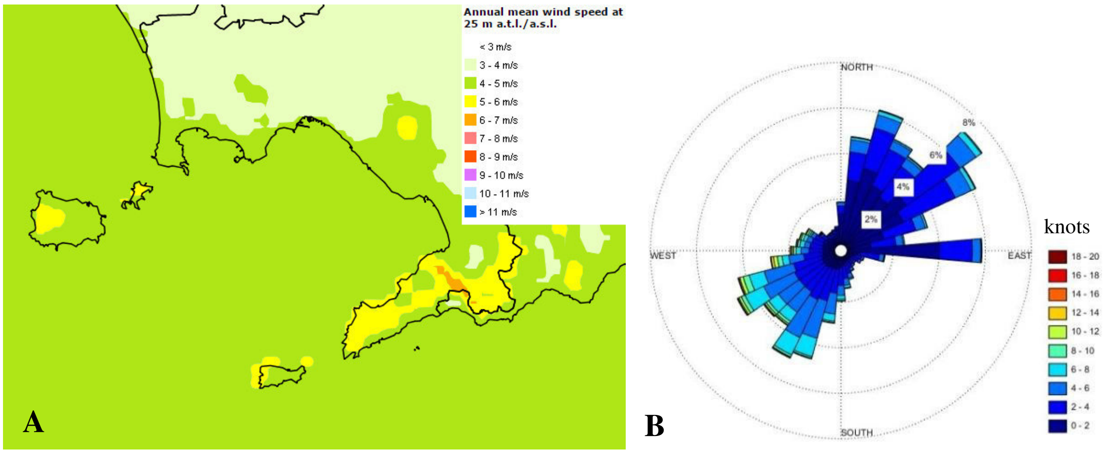


Figure 21: Annual mean wind speed at 25 m at sea level (A); Wind rose diagram of Naples station (B) (http://atlanteeolico.rse-web.it/index-en.phtml)

Notwithstanding the Tyrrhenian circulation of mid low zone are north-west directed, the Gulf of Naples and surrounding areas are interested by a weak and superficial south-eastward current. This is due to the dominant winds from the I and IV quadrant. This phenomenon leads also to an upwelling of deep waters from ‘Bocca Grande’ that affects the southern coasts of Phlegrean Islands. The exchange of water mass between the coast and the open sea is possible by the channels between Ischia and Capri (‘Bocca Grande’, Big Mouth) and between Capri and Punta Campanella (Bocca Piccola, ‘Little Mouth’) (Grieco et al., 2005). These mouths have respectively a threshold of 600-800 m and of 74 m depth. On the opposite, channels between Procida and mainland, and that between Procida and Ischia have shallower threshold (14 m and 12 m). A canyon, called Dohrn Canyon but known by fishermen as ‘Ammontatura canyon’, has important implications for the upwelling of deep waters relatively close to Posillipo coastline (Carrada et al., 1980).

The Gulf of Naples can be considered a semi-closed basin and with high trophic conditions. In particular, the Sarno River, with the anthropogenic releases, contributes to this trophic enrichment. This river (24 km long) is considered the most polluted river in Europe (Arienzo et al., 2001; De Pippo et al., 2006; Albanese et al., 2013) with uncontrolled outflow of domestic, agricultural and industrial untreated effluents). The river became very polluted since 20th century when several types of wastes from urban agglomerates, agriculture and industries (pesticides, leather and tomato resulting compounds) were directly discharged. Sometimes the river turns red because of the tomato production waste of the famous San Marzano tomatoes, nicknaming the river as ‘Rio Tomato’.

Although the mouth of Volturno River (another polluted River) is located in the bordering Gulf of Gaeta, its episodic emissions (mainly in spring-summer time) determine the formation of filamentous aggregates developing in the north side of the Campania regions for many kilometres. In that sense the influence of this river in the north side of the gulf is likely to be very important (Iermano et al., 2012).

2.2.2 Habitats and species diversity

The environmental quality of marine ecosystem has been directly influenced by the last hundreds of year of human activities (touristic, commercial and industrial) and the water masses have hydrographic and biological properties reflecting these anthropogenic stresses (Ribera d’Alcalà et al., 1989; Carrada et al., 1980; Zingone et al., 1990, 2010).

The complex geomorphology of the area along with natural and anthropic processes resulted in a highly diversified series of habitats and biocenosis, with a high biodiversity. The most important biocenoses (Bellan-Santini et al., 2002) are present; photophilous algae (AP), superficial muddy sands in sheltered waters (SVMC), *Posidonia oceanica* meadows (HP) and other seagrasses, coarse sands and fine gravels under the influence of bottom currents (SGCF), coralligenous (C), and semi-dark caves (GSO) are included (Russo et al., 2008; Simeone et al., 2016a,b). In particular, seagrasses dominate the north-western bottoms of the gulf and all around the islands; the south-west floor is characterized by different slope and very deep cliffs and hosts numerous caves with rare and peculiar species (biocenosis of dark caves, SGO).

Founded by the Italian Ministry of the Environment Land and Sea, a program aimed to establish the extension of the marine habitats indicated by the European Community Habitat (92/43/CEE) and according to Natura 2000 was performed and Sites of Community Interest (SCI) were identified (Gambi et al., 2009; Cigliano et al., 2009). 7 transitional and 4 marine areas were highlighted; in particular the marine areas are coincident with Marine Protected Areas (MPA).

They are: ‘Regno di Nettuno’ (Ischia, Procida and Vivara) (Gambi et al, 2003b), ‘Parco Sommerso di Baia’, ‘Parco Sommerso di Gaiola’ and ‘Punta Campanella’. A Protected Biologica Area (Zona a Tutela Biologica, ZTB) has been established too; it is ‘Banco di Santa Croce’, also called as ‘Secca di Vico Equense (Zupo & Buia, 2000) (Figure 22). Main features of these protected areas are summarized in Table 2. Although Capri was initially included in the feasibility study of the ‘Regno di Nettuno’ MPA (Russo & Ribera 2001), no protection measures were taken afterward.

In some of the MPAs of the Gulf of Naples, management actions are poorly documented and enforcement is ineffective. The most striking case is the Regno di Nettuno MPA (Ischia, Vivara). After the establishment in 2007, no real management actions have been performed so far, so the current situation is that only a designation exists. Baia and Gaiola are protected at least from an archaeological point of view, but illegal fishing activities are anyway frequent, especially in Baia. In Gaiola there is a bigger enforcement due to the small surface and vicinity of the MPA office and harbours, but only in recent times MPA management plans have been started to be taken into account and illegal harvesting of mussels, sea urchins and illegal spearfishing (often with air tanks) are still performed. Punta Campanella resulted as the most properly MPA managed in the gulf despite its high extension and the still very common illegal fishery, especially date mussel harvesting.

Table 2: Marine parks in the study area

Name	*Location*	*Cover (ha)*	*A zone (ha)*	*Establishment (year)*	*Enforcement Level*	*Reserve Effect*	*Web Site*	*Reference*
Regno di Nettuno	Ischia and Vivara	11,256	200	2007	none	not available	www.nettunoamp.org/	D.M. 27/12/2007 - D.M. 88 del 10/04/2008 D.M. 30/07/2009
Parco Sommerso di Baia	archaeological underwater ruins of Baia	177	21	2002	none/very low	not available	www.parcoarcheologico sommersodibaia.it/	D.I. 7.08.2002
Parco Sommerso di Gaiola	Gaiola Island, Trentaremi, Banco Cavallara	42	7	2002	relatively high	not available	www.areamarinaprotettagaiola.it	D.I. 7/8/2002
Banco Santa Croce	submerged banks	300 ha (0,3%)	na	1993	good	not available	http://www.biomareweb.org/3.4.html	Decreto MIPAF 15/06/1993
Punta Campanella	Promontory of Sorrento and Amalfi peninsula. (Naples - Salerno)	1,539	181	1997	good	(Fraschetti et al. 2005; Guidetti et al. 2008)	www.puntacampanella.org	D.M. 2/12/1997

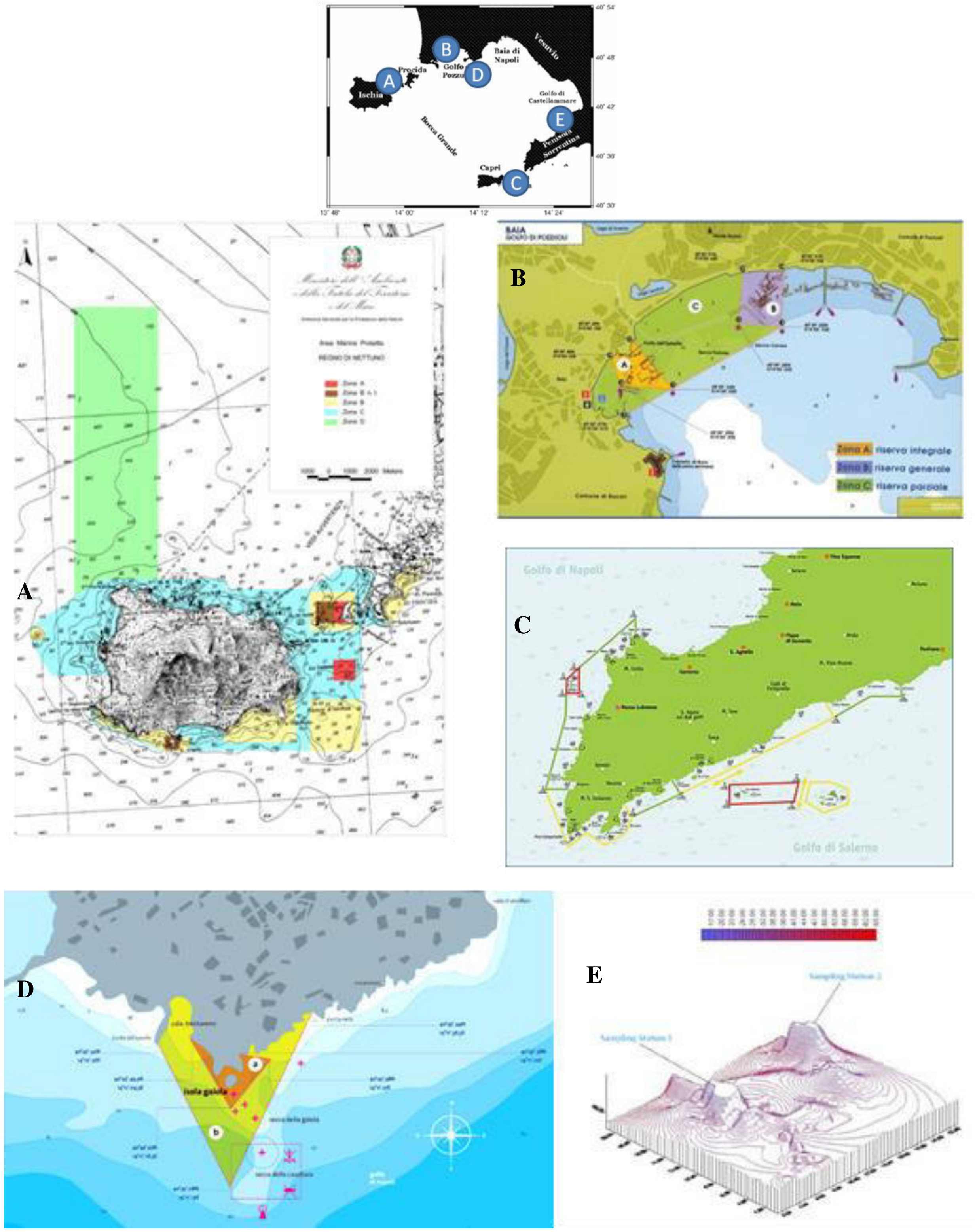


Figure 22: Zonation of the 4 MPAs in the study area: ‘Regno di Nettuno’ (A), ‘Parco sommerso di Baia’ (B), ‘Punta Campanella’ (C), ‘Parco Sommerso di Gaiola’ (D), ‘Banco di Santa Croce (E)

2.2.3 Benthic marine flora

Marine flora of the Gulf of Naples was deeply investigated since the foundation of the Stazione Zoologica di Napoli (SZN), in 1872. Reinke, Falkenberg, Solms-Laubach, Bertold, Valiante and Funk have been the first botanists that substantially contributed to the botanical knowledge of this area, a reference point for many researchers all around the world (Soria & Buia, 2008). They significantly gathered important knowledge on the seaweed biology and lead to the compilation of monographs published in the series "Fauna und Flora des Golfes von Neapel und der angrenzenden Meeres-Abschnitte". Some pictures are actually unrivalled today (Valiante, 1883). The greatest contribution to the study of marine botany of the Gulf of Naples was given by the German botanist Georg Valentine Funk (1927, 1955) that studied at the SZN over almost 50 years. After Funk's death, in 1958, a noticeable lack in phycological research was registered until the beginning of the seventies, when the research line was mainly focused on the biology and ecology of single species. However, relevant information testifying the first changes in the floristic richness of the gulf came from Bacci et al. (1972) and from Carrada et al. (1974). The latter authors, in the frame of a research on the coastal eutrophication from Portici to Pozzuoli, found an increase of nitrophilic species in comparison to Funk's observations (1927); this algal increase corresponded to high concentrations of nitrites, nitrates, and phosphates in the water. Bacci et al. (1972) listed some invertebrates and macrophytes disappeared in comparison with those previously observed by Funk (1955) (Table 3).

Table 3: List of macrophytes disappeared in some sectors of the gulf according to Bacci et al. (1972)

S.Lucia and Castel dell'Ovo (C)	*Acetabularia acetabulum* and coralline assemblages at 15 m depth
Posillipo Coastline (C)	*Caulerpa prolifera*
Posillipo (Cinito) (C)	*Caulerpa prolifera* and *Posidonia oceanica;* only few shoots occur
Pozzuoli Gulf (B)	*Posidonia oceanica*

In the last decades, driven by the Water Framework Directive, in the frame of researches on adaptive responses of species and communities to natural environmental variability and anthropic pressures (including climate change) the interest on brown algae raised (Soria, 2008; Porzio, 2011, Porzio, 2013; Chiarore et al., 2013, Kumar, 2015).

A first review of Neapolitan algal flora from 1878 to 2008 was done by Soria (2008, 2009). After nomenclatural updates, Soria (2008) reported 561 species: 381 Rhodophyta, 110 Ochrophyta and 73 Chlorophyta, representing respectively the 68, 19, and 13 % of the total amount of species (Figure 23). The comparison with the richness of Italian marine macrobenthos (Furnari et al., 2003, Furnari, 2010) highlighted the importance to protect the high alga diversity of this area (Figure 24).

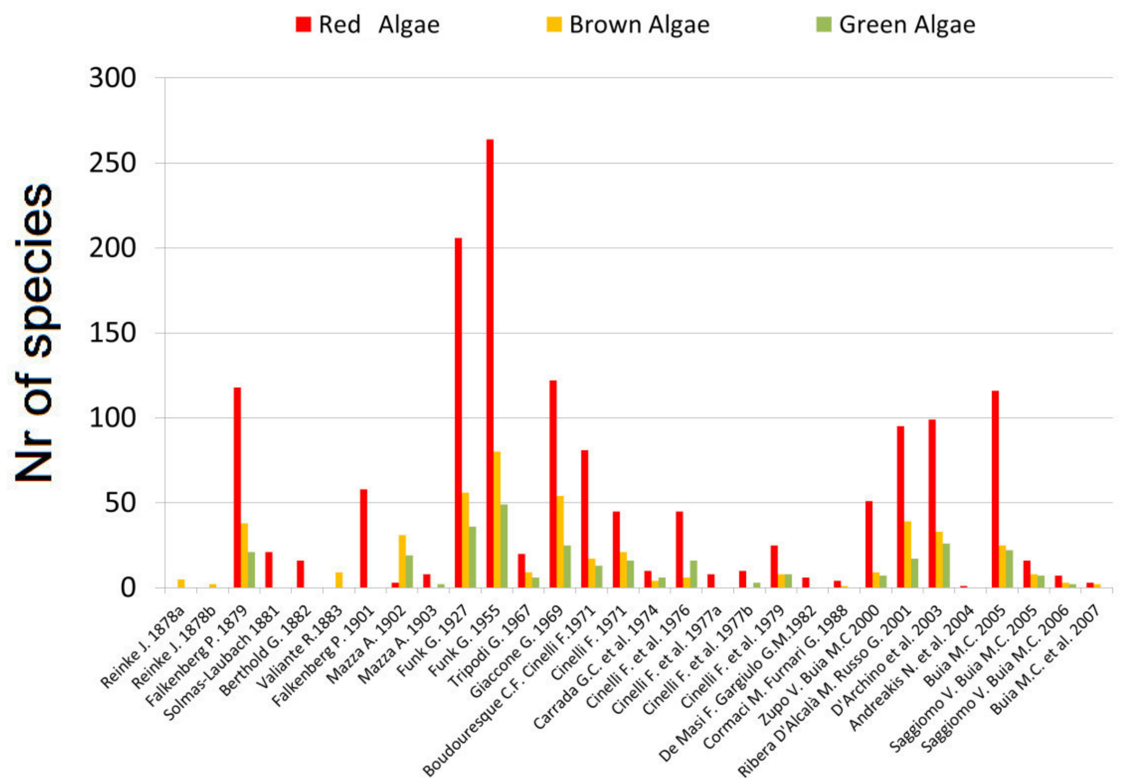


Figure 23: Number of species recorded in the Gulf of Naples in the time lag 1878-2007 (bar colours indicate different algological groups) (from Soria 2008, modified)

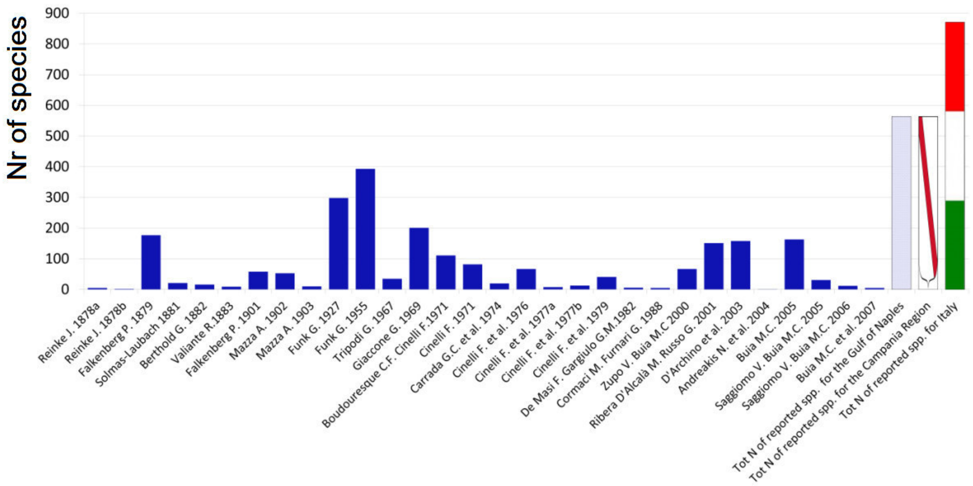


Figure 24: Total number of algal species according to different authors at local, regional and country levels from 1878 to 2007

The comparison between floristic data available in the literature for the two periods ‘1860-1955’ and ‘1956-2007’, highlighted that about 132 taxa (ca. 24%) were recorded only in the first period, while 126 species (approx. 22%) represented new records for the Gulf of Naples. Species present only in the first period and species present only in the second period were assigned to phytogeographic groups; in the last 60 years a decreasing trend of cold affinity species was evident in contrast to an increase of cosmopolitan species (Buia et al., 2013a; Figure 25).

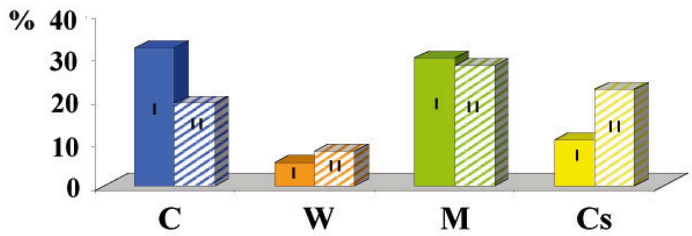


Figure 25: Temporal macroalgal richness in the Gulf of Naples according to their phytogeographic affinity. (I= 1860-1955, II= 1956-2007; C=cold; W=warm; M=Mediterranean; Cs=cosmopolitan and sub-cosmopolitan) (Buia et al., 2013)

The lower percentage of cold affinity elements in the second period could reflect the interaction between the ongoing climate change and the increasing of global trades, in particular maritime transports (Flagella et al., 2006, 2007).

Six macroalgal alien species are listed in the gulf; *Caulerpa cylindracea* (Buia et al. 2003b), *Womersleyella setacea* (Guala et al., 2006), *Acrothamnion preissii* (Ribera D'Alcalà & Russo, 2001; Buia, 2005), *Asparagopsis armata* (Funk, 1955), *Codium fragile* (Cecere et al., 2014) and *Lophocladia lallemandi* (Buia, pers.obs.) have been recorded. *Asparagopsis armata* and *Caulerpa cylindracea* showed an invasive pattern. A maërl facies along Ischitan coast has been described by Babbini et al. (2006) between 50 and 65 m. The species *Phymatolithon calcareum* and *Lithothamnion corallioides* are both included in the Annex V Habitat Directive of European Commission (CE) as species deserving protection.

In the Gulf of Naples there are 3 of the 5 seagrasses of Mediterranean Sea (Procaccini et al., 2003): *Posidonia oceanica* (L) Delile, *Cymodocea nodosa* (Ucria) Aschers. and *Zostera noltei* Hornemann. *P. oceanica* meadows were extensively studied, mainly around the island of Ischia (Colantoni et al., 1982; Mazzella & Russo, 1989; Buia & Mazzella, 1991; Mazzella et al., 1992; Zupo et al., 2006a,b) The highly variable environmental conditions and sea bottom topography of the island have favoured the diversification of *P. oceanica* meadows in terms of physiognomy (continuous and patchy beds), depth range (from 0 down to 38 m in depth), shoot density (from a mean of 900 shoots/m^2 at 1 m to 80 shoots/m^2 at 30 m depth) and biodiversity of associated communities (Buia et al., 2000, Procaccini et al., 2003; Gambi et al., 2003a and references therein). Long-term studies carried out since 1979 at the permanent station of Lacco Ameno (part of the international network LTER -Long Term Ecological Research) (Zingone & Buia, 2012) have detected a progressive deterioration in the bed off Lacco Ameno, probably as a result of mechanic pressures such as anchoring (not regulated), fishery and of a nearby wastewater outfall (Buia et al., 2003a; Zupo et al., 2006 a,b and references therein).

Different is the status of *Posidonia* meadows in the vicinity of the metropolis. The regression of the prairie in comparison with past data (Funk, 1927; Parenzan, 1956; Colantoni, 1982), detected by Buia (pers. obs.), has been currently confirmed (Simeone et al., 2016a,b) from Posillipo to Nisida, where huge extensions of dead matte of *Posidonia oceanica* have been recorded. On the opposite, even if there are no quantitative data, *Posidonia* meadows around the island of Capri seem to be well preserved (Buia, pers. obs.).

2.3 Main anthropic activities in the area and their impacts

2.3.1 Coastal development and loss of habitats

The Mediterranean coast is one of the world's leading holiday destinations and in some countries coastal tourism represents up to 90% of all tourism; the annual crowd is projected to increase to 235–350 million tourists by 2025 (UNEP/MAP, 2005). The development of infrastructures to sustain tourism and commercial activities, added to the increasing coastline urbanization and related coastal erosion, are the major anthropogenic pressure responsible for physical alteration, habitat fragmentation and destruction of natural marine ecosystems (Lotze et al., 2006; Halpern et al., 2008). The development of mitigation measures to respond to the problem of coastal erosion have further led to various constructions, such as breakwaters, jetties, seawalls and pilings, that have become ubiquitous features of intertidal and shallow zones, altering the marine habitats (Airoldi & Beck, 2007; Vaselli et al., 2008; Bulleri & Chapman, 2010; Claudet & Fraschetti, 2010). The Gulf of Naples was widely inhabited since the Roman era; the cities of Cuma, Baia, Pozzuoli, Ercolano, Pompei and Stabia are compelling witness of the ancient colonization as well as underwater ruins in the 'Parco Sommerso di Baia and 'Parco Sommerso di Gaiola' (Simeone & Russo, 2005; Bertini et al., 2015). The city of Naples has been historically on the top regarding human presence. Since 17th century it was ranked at the second position in Europe (after Paris) and at the fifth in the world. From about 600.000 inhabitants at the beginning of 1900, after the World War II the area was populated by more than 1 million of persons; at present time this value has been maintained while the metropolitan area reached 3 million of residents (Figure 26) (Geoportale Nazionale, 2015).

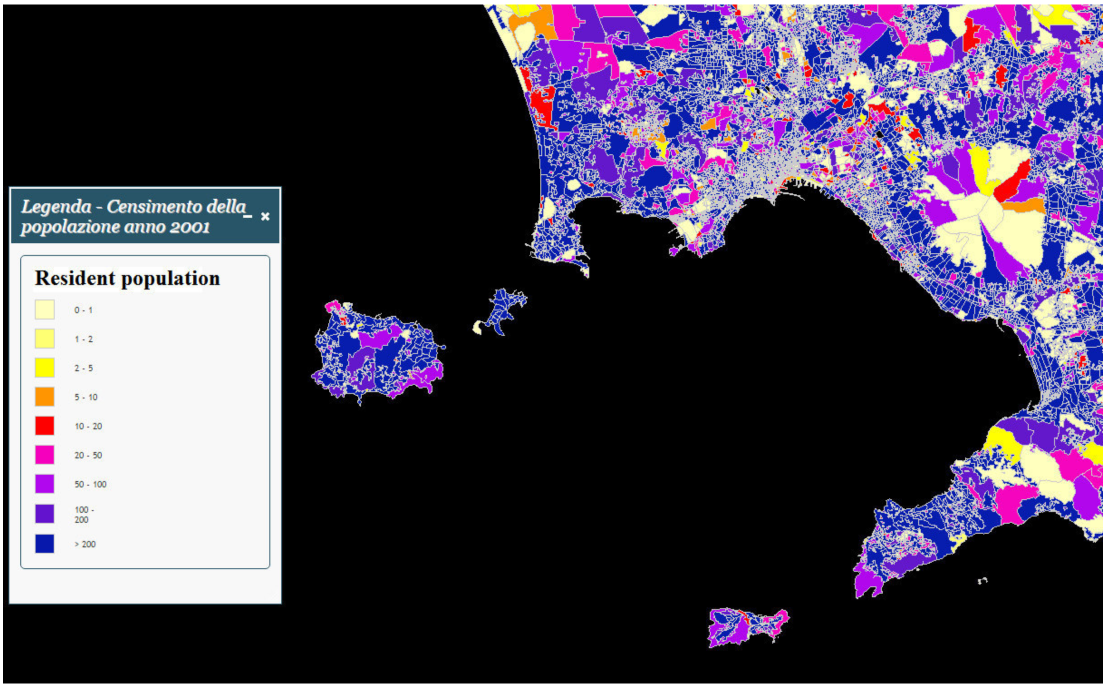


Figure 26: Resident population in the Gulf of Naples updated to 2001 (Geoportale Nazionale, 2015)

As a result, the land use cover (only expressed as artificial surfaces) shows the high urbanization level of the area (Figure 27). It is worth to note that important factories (i.e. ITALSIDER, Cementir) were built along the coast line together with about 30 ports and more than 300 maritime constructions (www.difesa.suolo.regione.campania.it). In particular, only the harbour of Naples covers an area of about 1,400,000 m^2 and the 'Angioino' dock (for passengers ships) is the greatest maritime station of the world covering an area of 12,000m^2 (Flagella et al. 2006).

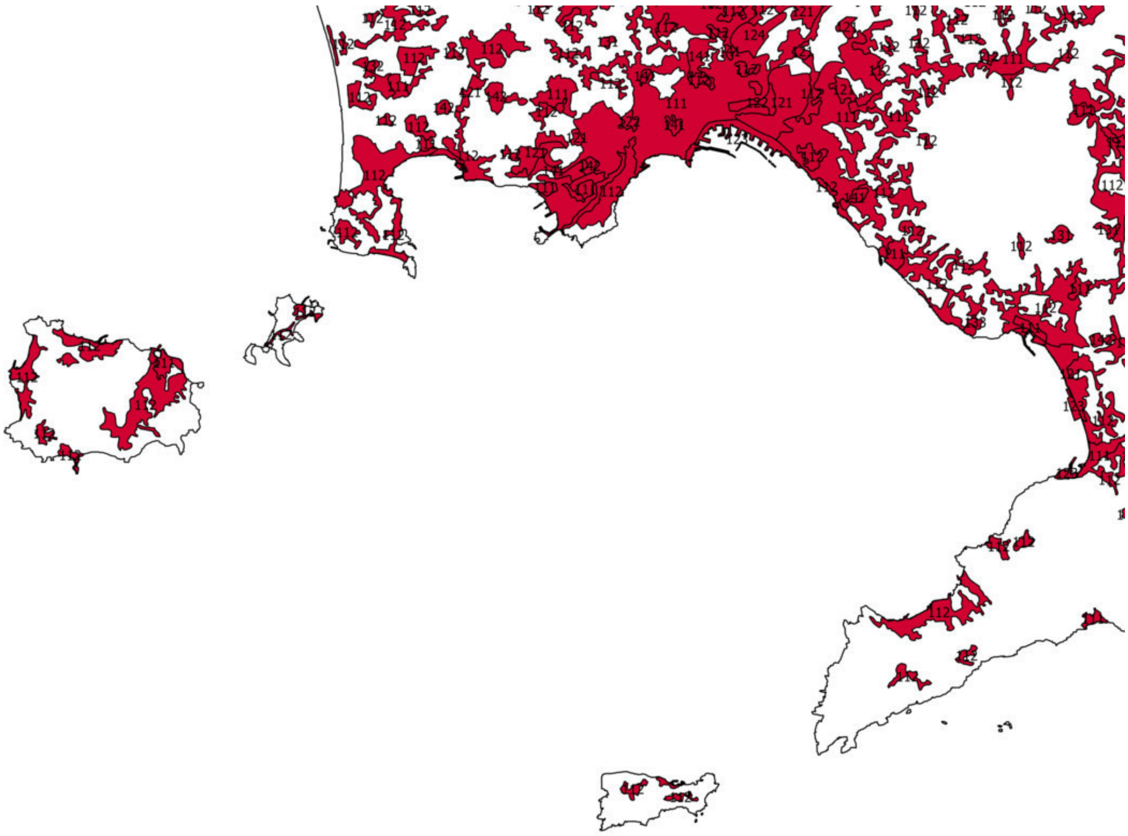


Figure 27: Land use cover by artificial surfaces in the Gulf of Naples (http://www.pcn.minambiente.it/GN/accesso-ai-servizi/servizi-di-visualizzazione-wms)

In order to quantify the level of the coastal artificialization in different sectors of the study area (the Gulf of Naples; this name indicate the whole study area), first of all I have divided it in different sectors; they were: (A) Ischia, Procida and Vivara islands; B: Pozzuoli Bay; C: Bay of Naples or Naples Bay; D: Sorrento peninsula; E: Capri Island (Figure 28).

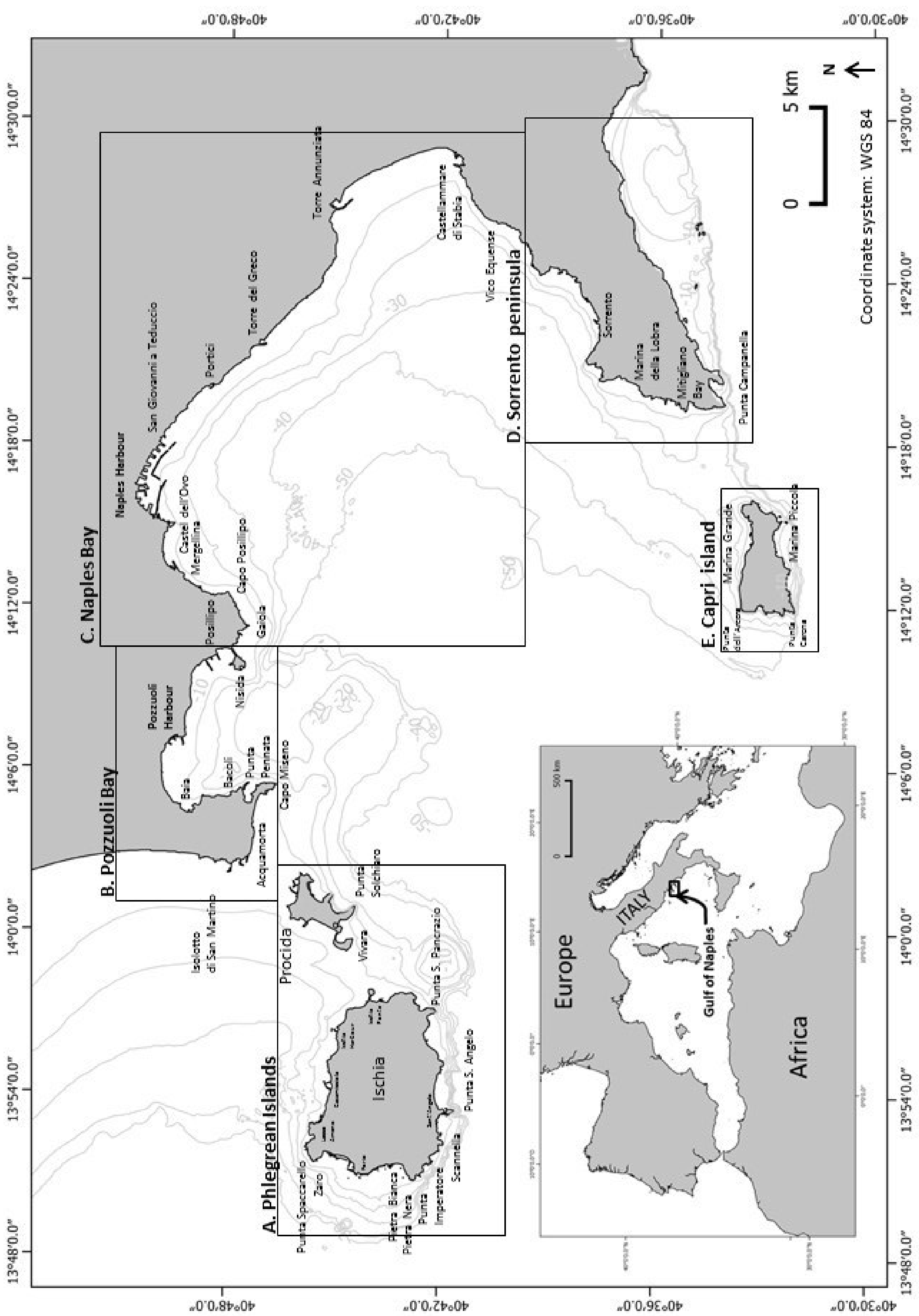


Figure 28: The five sectors in which the Gulf of Naples has been divided

Later, I have evaluated the current coastal transformation of the gulf by using ortho-photos selected from Google Earth. In particular, transects of 150 m long were selected and plotted along the shoreline. For each transect the percentage of natural/artificial coastal extension has been estimated and related to the total coastal length. Every kind of artificialization has been taken into account: harbours, marinas, docks, breakwaters, jetties, seawalls and pilings.

Results attested an artificial costal development of about 34% of the total coastal length, equivalent to 70 km coastline. The sector with the highest percentage of artificial coast was the Bay of Naples while Capri had the lowest one (Table 4).

Table 4: Evaluation of the percentage of natural/artificial coastal extension in the five sectors of the Gulf of Naples per each side of sector, each group and total contribution of each sector to the total percentage

		Total length (m)	*Natural length (m)*	*Artificial length (m)*	*Artificial %*	*Artificial % (per each group)*	*Artificial % (contribution of each sector to the total percentage)*
Ischia (A)	**North**	10570	5110	5460	**52**		
	East	6895	5405	1490	22		
	South	13872	13192	680	5		
	West	7160	5085	2075	29	**25**	
Procida (A)	**North**	2850	1920	930	**33**		
	East	6601	6029	573	9		
	South	3300	2738	563	17		
	West	4177	4117	60	1	**13**	
Vivara (A)	**Vivara**	3300	3296	4	0	**0**	***6***
Pozzuoli Bay (B)	**Western Miseno**	6000	3803	2168	36		
	Eastern Miseno	7950	6098	1853	23		
	Pozzuoli city	8250	3645	4605	**56**		
	Pozzuoli ex Italsider	9150	2468	6713	**73**	**49**	***7.5***
Naples Bay (C)		57198	21105	36093	63	**63**	***18***
Sorrento Pen. (D)		29161	24832	4329	15	**15**	***2***
Capri (E)		26788	25746	1043	4	**4**	***0.5***
	TOTAL (km)	**203.2**	**134.6**	**68.6**			***34%***

Among the Phlegrean Islands (A), the northern side of Ischia recorded a massive urbanization (52%) as well as the northern side of Procida (33%). Both these sides host the main harbour and marinas. Changes are evident when pictures of the same sites but at different time are compared. In the Figure 29 are reported old and current landscape photos of some zones of the north side of Ischia where the coastal zone experienced a dramatic change.

Figure 29: Old (1920-1930, on the left) and current (2015, on the right) shoreline landscapes of three sites on the northern coast of the Ischia Island

In this sector A, Vivara, a private isle and registered as natural reserve, has no artificial coast (Figure 30). Due to inheritance issue, the entrance to the isle is forbidden since 1999 to everybody.

Figure 30: Vivara Island and its connection to the Procida Island by a bridge, on the background the island of Ischia (from www.napolilike.it)

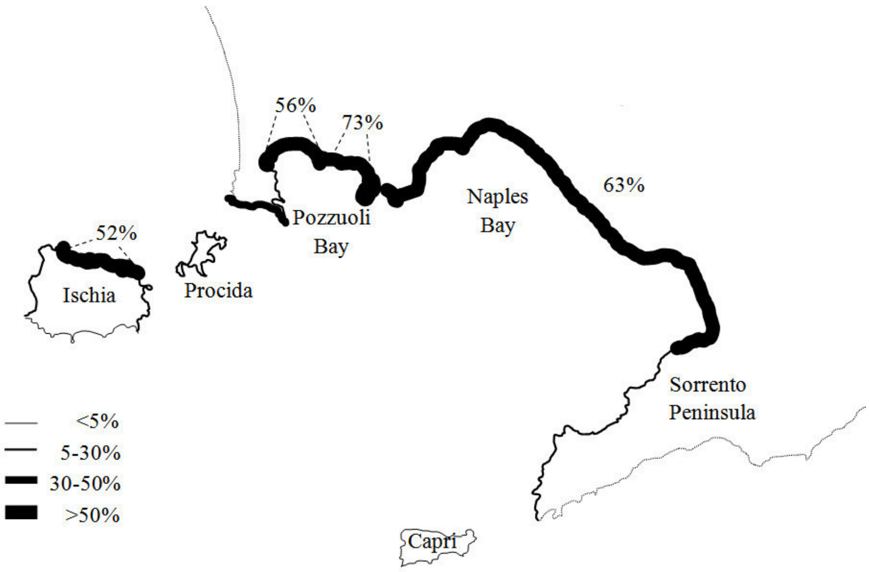


Figure 31: Percentage of coastal transformations in different sectors of the Gulf of Naples (from Grech et al., 2015b, modified). The thickness of coastline line represents the percentage of artificial coast development

About half of the coastal length of the Pozzuoli Bay is artificial (Sector B: 49%), mainly due to the factories settlement in the 1960s (Albanese et al., 2013) on the eastside of the Bay for several kilometres (Pozzuoli-city: 56% of artificial coast; Pozzuoli-Ex Italsider: 73% of artificial coast; Figure 31). An evaluation of the total surface reclaimed from the seabed (surface of habitat loss) has been computed for Ischia Island (Sector A) through satellite image analysis and it amounts to

26.8 hectares; this surface corresponds to an area that has been artificialized mainly by the deployment of emerged and submerged breakwaters (Figure 32) located in the north, north-east and south side of the Ischia island.

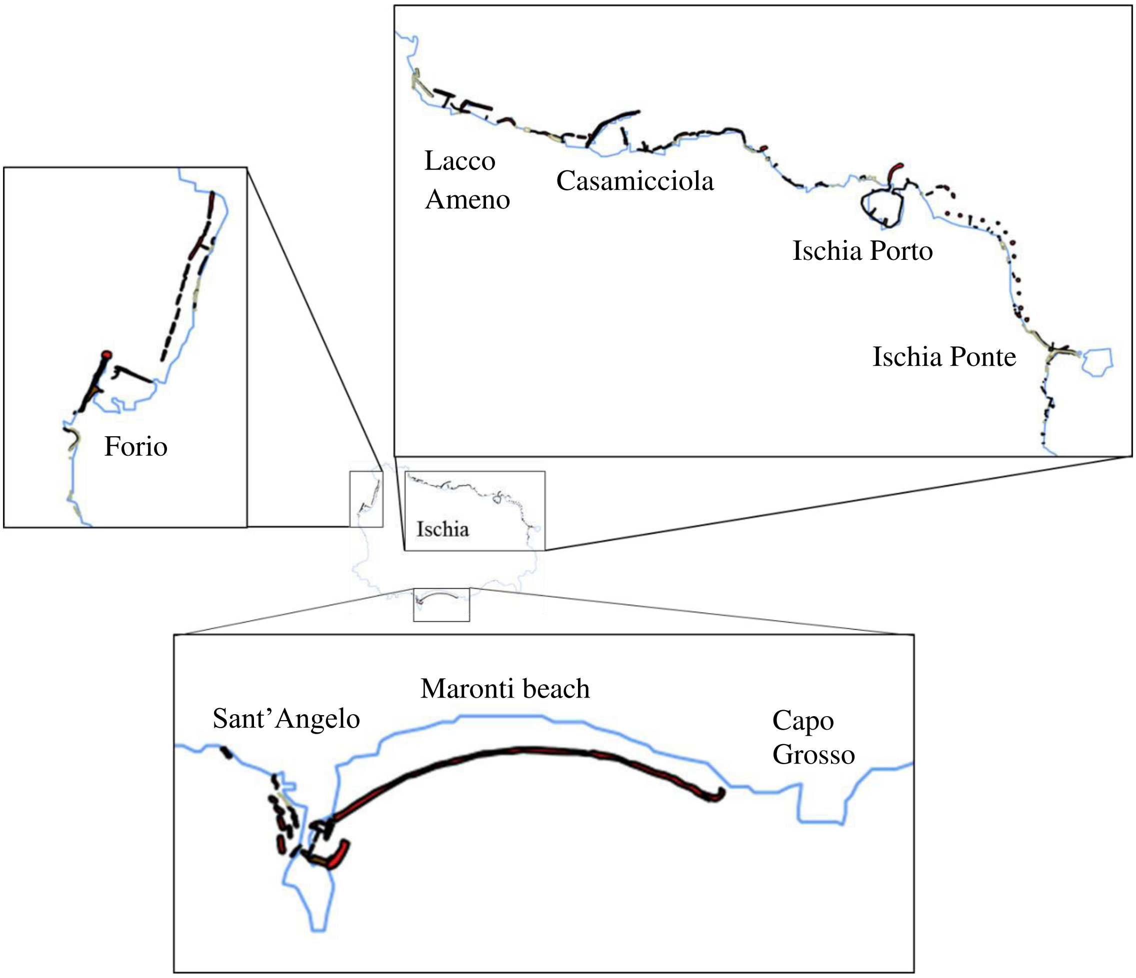


Figure 32: Dislocation of artificial structures around the Ischia Island

Another example of the temporal changes occurred along the coastline is Nisida (Figure 33); it was an isle until 1938, but later, during the settlement of one of the largest steel factory, was connected with the mainland. Moreover, in the Figure 34 another example of historical coastal changes is reported: in front of the Stazione Zoologica at Naples the long sandy beach has been lost and transformed in one of the main busy road of Naples, Via Caracciolo. These changes of the coastline resulted in a huge habitat destruction and loss with the introduction of a novel habitat, different from the previous one, with a different lithology and micro-spatial heterogeneity.

It is worth noting that, although part of this artificialization was done with the purpose to contrast beach erosion, the gulf is suffering a substantial erosional phenomenon of sandy beaches. Phlegrean islands experienced in the last 40 years a sandy shores loss between 65-50%, corresponding to a surface of about 140,000 m^2 (Zucco, 2003). The most famous case is the Maronti beach (Ischia) (Gambi et al., 2005).

Figure 33: Nisida, before 1936 (up) and current landscape (down) after the abandoned Italsider-Cementir settlement (Giorgio Sommer's picture)

Figure 34: Coastal land transformation in Naples ('Napoli Retrò' social network group)

2.3.2 Sewage outfall

In coastal ecosystems, sewage water outfall is a very common source of disturbance with documented structural and functional alteration of coastal marine ecosystems (Fraschetti et al., 2006). Notwithstanding European directives such as the Marine Strategy Framework Directive (MSFD) planned to achieve and maintain the 'Good Environmental Status' (GES) along European coasts by 2020, the Italian control and efficiency of national sewages treatment is scanty In fact, as it is evident in Table 5, in no Italian region the sewage network cover the whole administrative area nor the quality of the treatment is high.

Table 5: Percentage of sewage network cover and depuration treatment cover of the sewage outfalls in different Italian regions (na = not available) (from Utilitas, 2009, modified)

Country	**Sewage network cover (%)**	**Depuration treatment cover (%)**
Piemonte	89.9	82.5
Lombardia	93.9	77.8
Liguria	75	74
Veneto	78.1	78.7
Friuli VG	na	na
Emilia R	84.8	78.7
Toscana	81.8	62.7
Umbria	77.1	78.2
Marche	84	69.9
Lazio	85.3	74.1
Abruzzo	89.1	72.6
Molise	86.4	84.5
Campania	**83.5**	**67**
Puglia	82.6	na
Basilicata	88.8	74.7
Calabria	88.3	74.5
Sicilia	78.8	53.9
Sardegna	75	68

Data from the Campania Regional Environmental Protection Agency (ARPAC) evidenced a high number of non-authorized outfalls all along its coast. In 2004, only 76% sewage outfalls in Naples compartment were authorized on 464 recorded. A sewerage system covered 83.5 % of the region, but a high percentage of sewages reached the sea without any treatment (Table 5). An overview on sewage systems and sewage depuration is depicted in Figure 35. Periodical ARPAC inspections revealed that the main parameters for which legal limits are not observed are: toxicity assay, nitrogen compounds, BOD5, COD, Total Tensioactives, *Escherichia coli*, Total Suspended Solids. The area in which most frequently these sewage systems were not compliant is the eastern part of the Sector C (Naples Bay). In conclusion for the year 2013 the depuration system of the gulf has been classified as poorly efficient.

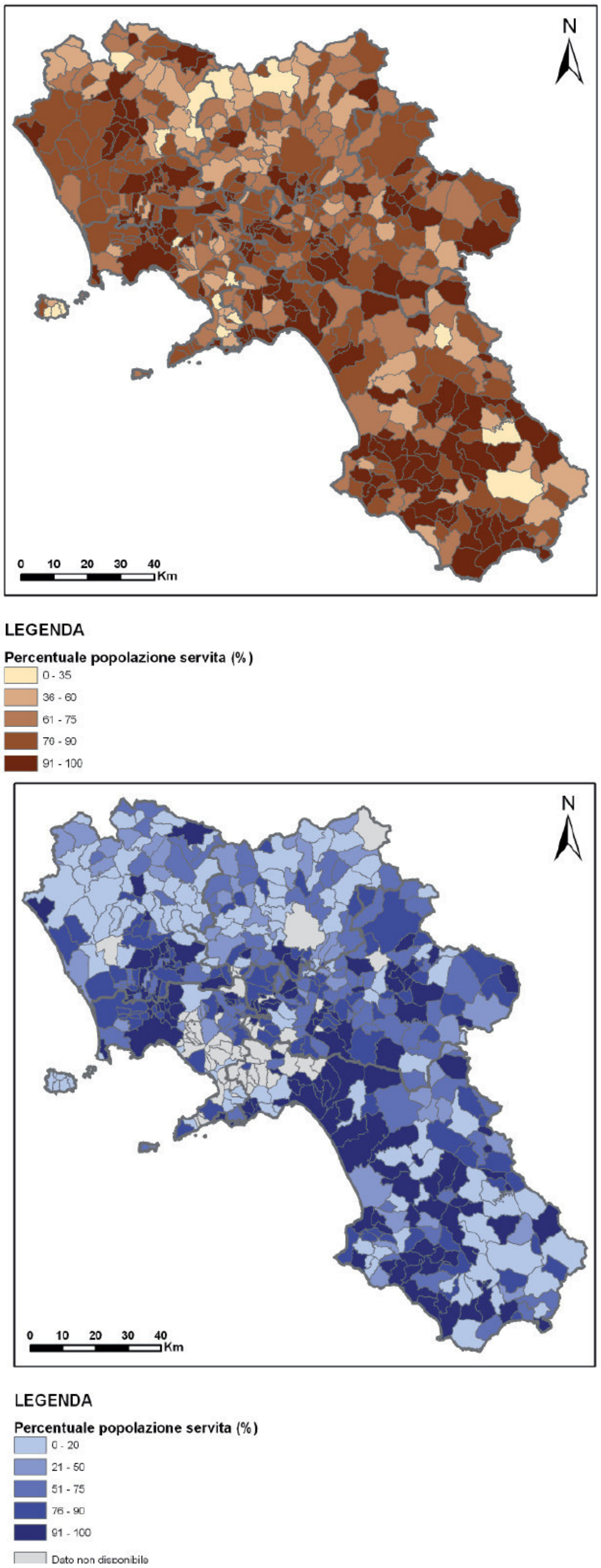


Figure 35: Percentage of population covered by the sewage network (left) and percentage covered by depuration service (right) in the Campania region (Adamo et al., 2009)

However these data can be controversial if the differences between sewages outfall are not explicit. In fact even if the percentage of banned coasts for the Campania region passed from 35% in 1990 to 22% in 2008, testifying a less ‘pollution degree’, the high efficiency of sewage outfall treatment (documented in Table 6) does not coincide with the statement of the east coast of Naples as the most contaminated by faecal bacteria (total coliforms, faecal coliforms, faecal streptococci, salmonellae and enteroviruses are included in the microbiological monitoring). It is evident that the number of non-official sewage outfalls is huge and there is not a detailed monitoring.

Comparable consideration derives observing the bathing level for the Gulf of Naples assigned by the Campania Regional Agency (Figure 36).

Table 6: Percentage of sewage treatment system efficiency in some localities of the gulf for 2013 (Report Programma Interventi Regione Campania, 2014)

Sector	Locality	Efficiency (%)	Population (nr)	Density (inh./km2)
C	Catellammare di Stabia	59.40	65,929	3,765
C	Pompei	0	25,397	2,046
C	Portici	98	55,537	12,287
C	Ercolano	0	53,972	2,748
C	Vico Equense	0	21,019	717
C	Torre Annunziata	63.75	42,868	5,848
C	Torre del Greco	95	86,793	2,831
D	Massa Lubrense	91	14,182	719
D	Meta	0	8,032	3,668
D	Piano di Sorrento	0	13,159	1,795
D	Sant'Agnello	0	9,102	2,225
D	Sorrento	50.96	16,724	1,684
E	Anacapri	98.3	6,926	1,084
E	Capri	95	7,224	1,82

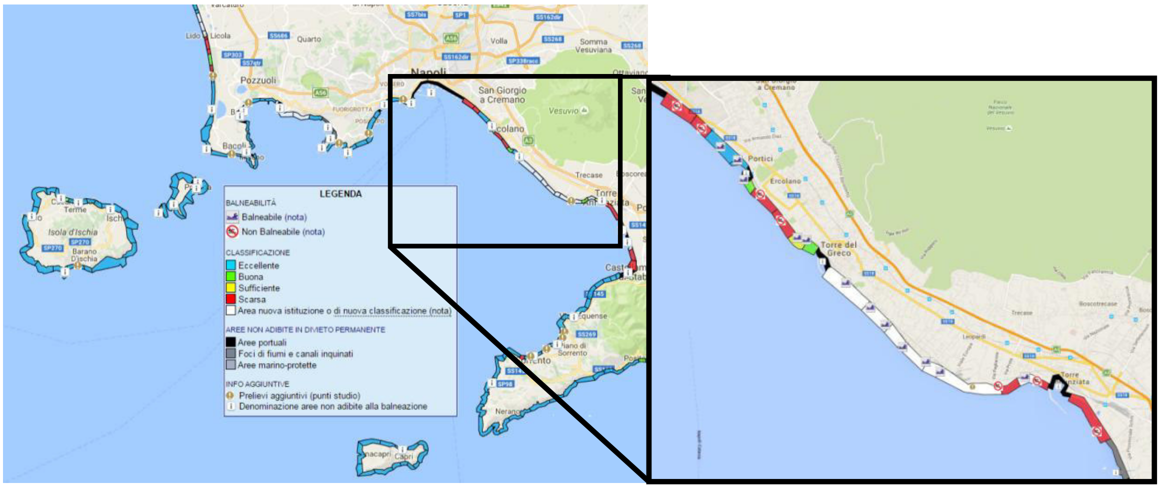


Figure 36: Bathing level assigned by the ARPA (2014)

In fact, in the frame of researches conducted to elaborate the Feasibility Plan of the Regno di Nettuno MPA, a section was devoted to describe some urbanistic and territorial features regarding Ischia and Procida Islands (Zucco 2003). In particular, on the Ischia Island the sewage systems does not cover totally the island but only the most urbanized areas and only the 10-15% of them are authorized by the Local Sanitary Agency (ASL). Ischia has 7 continuous untreated discharge outfall through pipelines and 2 without a depuration system (Ischia and Sant'Angelo), but with a very low efficiency. The building of a new depurative system of Ischia, started in 2003, has not been completed yet. A comparable situation is present in Procida with 7 discharge pipelines (Figure 37).

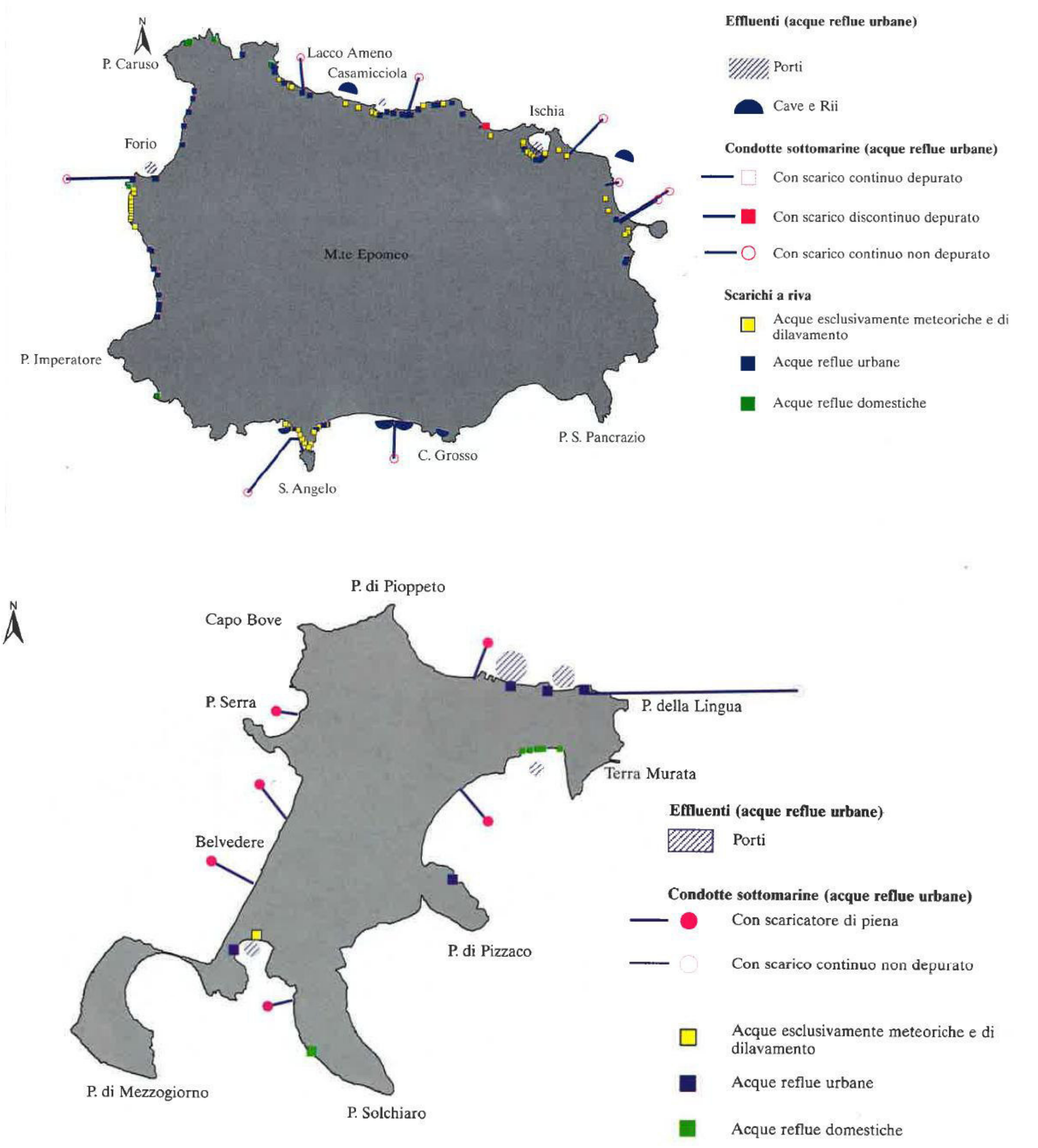


Figure 37: Official sewage outfall locations around the Phlegrean Islands (Zucco, 2003)

In addition, in the past the solid waste was not properly managed: in Ischia for many years a site in Zaro, near Punta Cornacchia, has been used as waste discharge, displayed by the coastal erosion showing plastics/soil/building materials/glass and cables (pers. obs.). Also Procida had a waste point located at Punta Solchiaro; there it is possible to find motorbikes, cables, scrap metals into the seafloor. Currently, on both the islands the waste is transferred to the mainland.

In the Sector B, sewages were historically discharged for decades directly into the sea or into the retrodunal lagoons (e.g. at Bacoli the Miseno lagoon). This area only in recent years has been restored with the development of a pipeline reaching the Cuma water plant treatment.

It is worth of mention that in general historical occurrence of sewage treatment is really difficult to reconstruct, but it was probably worse than the current one, as it results from Carrada et al. (1974). They found a very high polluted water (Figure 38) in the two industrial areas of San Giovanni a Teduccio (Bay of Naples - Sector C) and Bagnoli (Bay of Pozzuoli – Sector B) while in the area close Posillipo (Sector C) the values were similar to those found far from the coast. Analysing the algal assemblages and comparing current data with those recorded by Funk (1927) 40 years before, they assumed an increase of the pollution due to the dominance of nitrophilic species (i.e. *Pterocladiella capillacea Ulva rigida*, *Petalonia* sp. and *Lyngbia* sp.

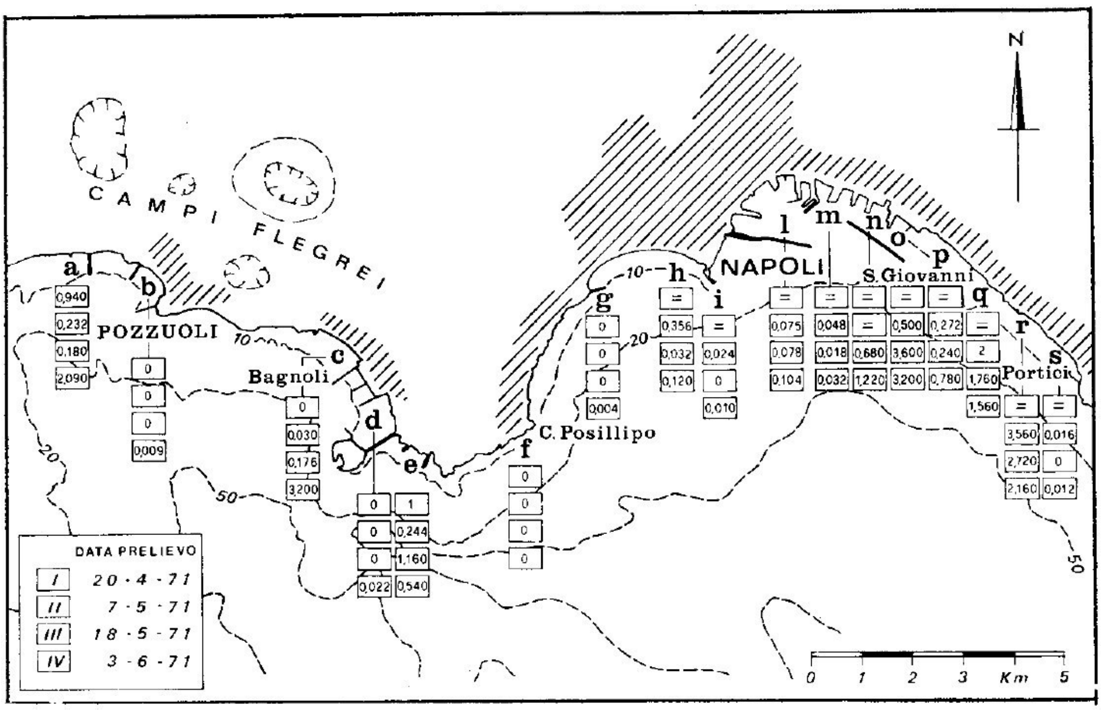


Figure 38: Phosphates values recorded in 1970s in the Bays of Pozzuoli and Naples (values are expressed in mg/l) (Carrada et al., 1974)

2.3.3 Maritime traffic

The harbour of Naples covers an area of about 1,400,000m^2 and has a linear extension of 11,500 m; the water mirror (2,792,550 m^2) is deep between 11 and 15m. The harbour has 70 moorings for passenger and commercial trades and is multifunctional (shipyard, commercial, cruise, passenger, crude oil) (Flagella et al., 2006). The 'Angioino' dock (for passenger ships) is the greatest maritime station of the world covering an area of 12,000m^2. The harbour contains 3 additional dry docks, 1 on land able to lodge ships up to 50 thousand tonnages of tons and 2 floating ones (Flagella et al., 2006).

In 2001, Flagella and collaborators calculated that the Neapolitan harbour received about 37,000 arrivals per year: 25,000 hydrofoils, 6000 passenger ships and 6000 commercial arrivals, with a peak in August (Figure 39). As concerns the commercial traffic, the arrivals corresponded to a mean of 15 ships per day.

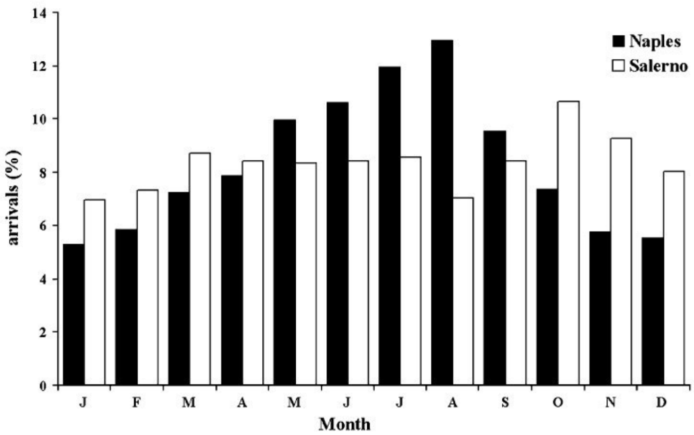


Figure 39: Monthly commercial arrivals (%) in Naples Harbour (black bar) compared to Salerno Harbour (white bars) (Flagella et al., 2006)

A more recent investigation has been conducted in 2011. Import was the main activity of the harbour with 370 companies, 5200 employees and revenues of 516 million of euros per year (Buia et al., 2013b). Other important harbours in the gulf are those of Pozzuoli (goods and passengers), Torre Annunziata (goods) and Castellammare di Stabia (ship-building industry).

Recreational traffic, with number of mooring place per harbour and total number of docking per year, is summarized in Figure 40.

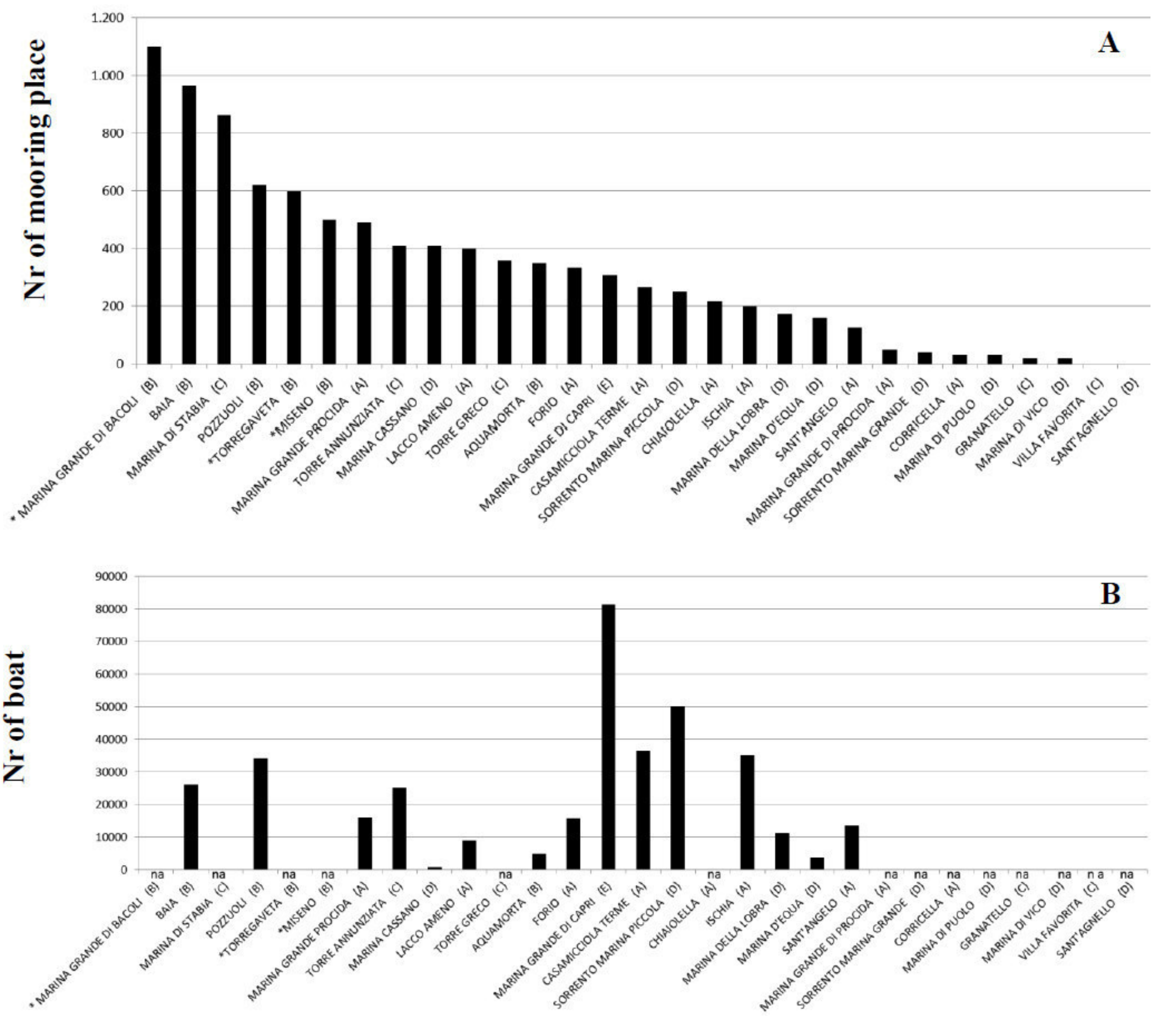


Figure 40: Total number of mooring places per harbour per year (A) and docking per year (B) (ARPAC, 2012)

These numbers have to be incremented by the huge amount of daily leisure boats freely mooring outside the ports, in several sites along the coastline. Generally, leisure boats anchor in sheltered places with low depth. According to that, many Capri seafloors far from harbours are naturally preserved from anchoring, due to high depths close to the coastline. The reverse pattern, due to the absence of bathymetric constrains, is observed in the Phlegrean Islands (A) and in the area of Baia-Miseno (B). Unfortunately, there are no quantitative data for the study area; as a general pattern when regulations are present, they are not observed (pers. obs.).

I gathered a rough estimation of anchoring pressure for the island of Ischia (Sector A) by visualizing pictures obtained by public webcams (http://www.consorziomaronti.it/; http://www.ilmeteo.it/webcam-mare/Barano+d%27Ischia) and by *in situ* personal assessment.

During spring-summer time a mean of 100 boats per day moored in the Maronti Bay and reached peaks of more than 400 boats/day in August (2014-2016). The frequency and preference were regulated by dominant winds. Besides Maronti Bay, other crowded Bays were Lacco Ameno (more than 100 boats in spring-summer period), San Montano, Chiaiolella and Corricella (Sector A). In the framework of MedPAN project (Simeone et al., 2016a), an evaluation along the Posillipo coast (C Sector) has been conducted. The highest mooring density has been recorded at Coroglio, Nisida and Marechiaro (Figure 41).

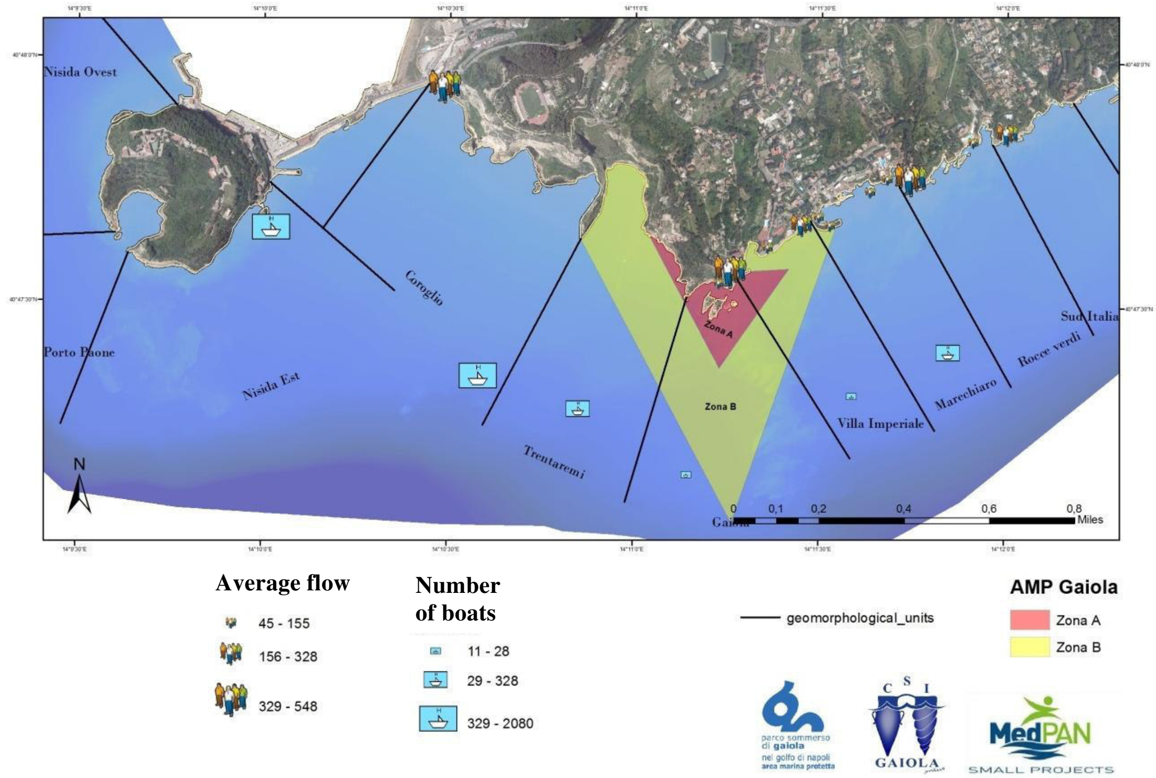


Figure 41: Mooring density along the Posillipo coastline (Simeone et al., 2016a)

As concerns the passenger traffic, the most important harbours are Ischia, Casamicciola and Procida (Sector A), Capri (Sector E), and Sorrento (Sector D) (http://www.capritourism.com/it/statistical-data). Ischia Island is the favourite destination for touristic activities (Figure 42) with 4-6 millions of travellers per years and a peak (600,000) in August (Osservatorio Turismo Campania, 2007).

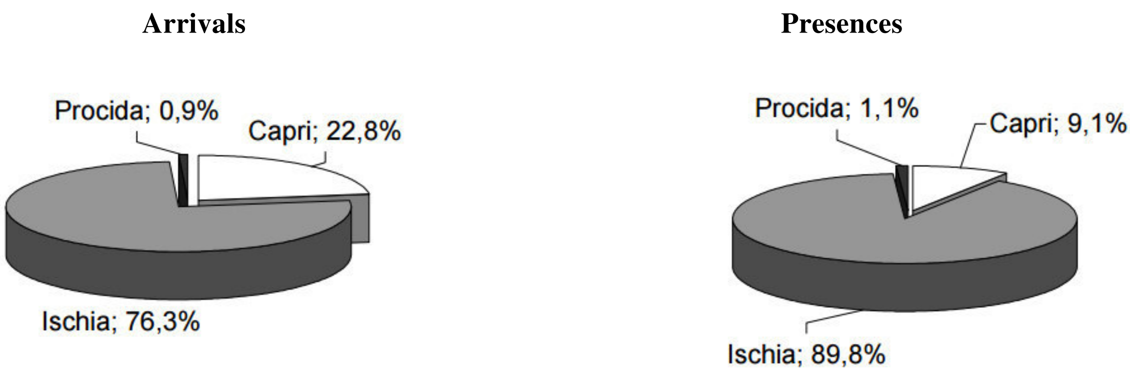


Figure 42: Tourist fluxes (%) in the Neapolitan islands between August and September 2006 (http://www.ontit.it/opencms/export/sites/default/ont/it/documenti/archivio/files/ONT_2007-11-01_00763.pdf)

2.3.4 Fisheries and Aquaculture

Due to the paucity of peer reviewed publications, we used grey literature or internal reports (unpublished data) to estimate the pressure and the putative impact of small fishery (fishing nets) and trawling on benthic ecosystem (Casola et al., 2004; Carbonara et al., 2014; Simeone et al., 2015b; Ferrigno et al., 2016). In addition, ichthyofauna of the Phlegran Islands (Sector A) has been poorly studied, mainly related to *P. oceanica* seagrass system. The most extensive works are those by Harmelin-Vivien & Francour (1992) and by Gambi et al. (2003a) in the framework of the MPA institution, listing a total of 48 species. The Santa Croce bank (Sector C) was investigated by Zupo & Buia (2000). A characterization of fish assemblages of the MPA Punta Campanella (Banco del Vervece) (Sector D) is available in Balzano et al. (2005).

After the World War II, the world fishery activities, strongly rooted on traditions and resistant to innovation, did giant leaps in the use of technology. As a matter of fact, there have been more innovations in the last hundred years than in the previous twenty centuries (Ferretti, 2011). Technical upgrading of the material from about 1950s (from natural, i.e. cotton to synthetic fibers, i.e. polyamide) led to fishing with longer nets. Ancient vegetable fibers were suitable but they were also putrescible and they had to be frequently treated; they every time had to be exposed to air in order to avoid or delay the rotting process. This long practice obliged fishermen to a huge work for drying, maintenance and anti-putrefaction treatments of their nets before fish expeditions (Ferretti, 2011). This lead to a number of fishing days per year relatively low. With the introduction of new fishnet materials and in the 1960s the advent of fishing winches with the increase of motor power, number of fishing days and impact into the seafloor increased dramatically.

Italy is a country with a high tradition of fishery. The Italian fishing fleet operating in the Mediterranean is made up of 13,064 vessels with 28,724 fishermen. It is one of the most important fleets in Europe, after Spain and England. The majority of the boats using gears (67%) belong to the "small fishery" (or traditional or artisanal fishery), a very important compartment for the Campania region (Unimar, 2010).

The unique overall available data-source was the Feet Register of European Commission (http://ec.europa.eu/fisheries/fleet/index.cfm). I queried the online database for the gulf (harbours of Casamicciola, Forio, Ischia, Procida (Sector A), Baia, Monte di Procida (Sector B), Napoli, Portici, Castellammare di Stabia, Torre Annunziata, Torre del Greco, Torregaveta, Vico Equense (Sector C), Sorrento, Massa Lubrense, Meta di Sorrento, Piano di Sorrento (Sector D), Capri (Sector E). The main fishery effort in term of number of vessels was recorded around the islands of Ischia and Procida (Sector A; N=253); set long lines (LLS) and purse seines (PS) and gillnets (GNS) are the main fishing gears used (Figure 43). Ischia fleet was the typical Tyrrhenian fishing fleet, composed mainly (95%) by artisanal fishery. Procida fleet is a bit more diversified (Fleet Register, 2012). They usually fish every day with no rest, but for bad wheatear conditions.

In the Sector B, 243 units are involved in total; dominant vessels are GNS and SLL, also the number of PS is relevant. This is the sector in the gulf with the highest number of registered vessels operating with gill nets.

In the Sector C, the most important gears are long lines, gill nets and bottom otter trawls (OTB), the latter with the highest value (N=49).

A lower fishing pressure is recorded in the Sector D even if the three main gears used are the same dominant in the sector A (same proportion of long lines, purse seines and gill nets).

The lowest pressure has been recorded for the island of Capri, with 35 fishing vessels: 2 boats mainly using gill nets, 25 long lines and 8 purse seines. For this sector, the distance from the most important marinas of the gulf seemed to be responsible of the lowest fishing pressure, probably mainly exerted by local fishermen.

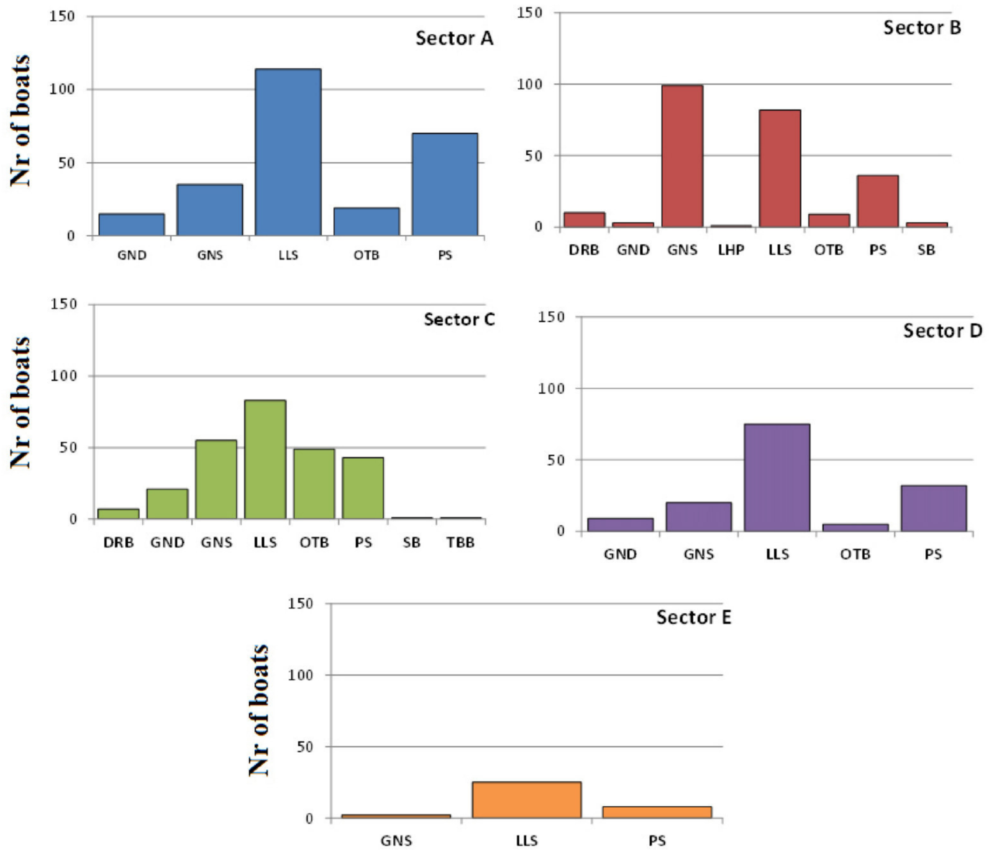


Figure 43: Composition of the fishing fleet of the Gulf of Naples (DRB: Boat dredges; GND: Driftnets; GNS: Set gill nets; LHP: Hand lines and pole lines; LLS: Set longlines; OTB: Bottom otter trawl; PS: Purse seine; SB: Beach Seines)

The differences highlighted among sectors (derived by local registers) do not perfectly correspond to the actual fishing pressure. This is true for the fishing activities exerted around the island of Ischia, implemented by 'foreign' vessels, coming from Pozzuoli, Monte di Procida and Procida Island as reported by local Ischitan fishermen. Due to this 'invasion' a different computation of the fishing pressure has to be done for the Phlegrean area (including also Pozzuoli, Monte di Procida, Procida, and Ischia); in this area the most employed type of gears were the longlines (39%) and gill nets (26%) on 262 fishing vessels currently operating.

In general, forbidden gears are commonly used, such as some illegal tricks to increase the performance of trawling nets. Moreover, Mussi & Miragliulo (2003) have been reported the occurrence of driftnet more than 25 km long (Figure 44A) around the island of Ischia. For this island, another recorded fishery activity is the deep red shrimps fishing with deep traps (Carbonara et al., 2014), less impacting than trawling.

Figure 44: (A) A forbidden driftnet in the Forio harbour (Ischia Island) in 2007 (Photo credit Oceana Campaign) and (B) a blast fishing residual (unexploded artisanal bomb) found in the sea floor, about 1990 (Virgilio Liguori). (C) The huge impact on benthic communities of date mussel harvesting, Vervece bank (Marco Gargiulo)

Other information about fishery in the gulf is very scarce. Casola et al. (2004) gave a characterization of the fishing fleet operating along the MPA Punta Campanella (Sector D). This fleet is one of the biggest among 18 fleets operating in the marine reserves, with 66 boats equipped mainly with trammel nets, gill nets and longlines. However, the institution of marine reserves in the gulf without any *a priori* stakeholders involvement has been negatively accepted by more than 60 % of the interviewed fishermen.

Additional impacting fishing activities have been recorded for the gulf. In particular, fishing with bombs (Figure 44B) was an usual practice in Ischia since 1950th up to 15-20 years ago, carried out especially on the south-east side (Punta Pisciazza) targeted to big schools of fishes. Besides bombs, mussel harvesting is still now very common in all sectors, despite a very strict legislation and the MPA institution. The impact on benthic communities is huge (Figure 44C), affecting the persistence of several algal and invertebrate species (e.g. *Codium bursa, Tricleocarpa fragilis, Chondrosia reniformis, Hemimycale columella, Ircinia variabilis, Petrosia ficiformis, Serpulorbis sp., Ciona intestinalis*) (Bevilacqua et al., 2006) but no information is available on fucalean species in this publication.

A spatial distribution of artisanal fishery pressure does not exist for the gulf. To overlap this gap, I performed a query for the island of Ischia only, showing a map of the island with a superimposed grid to fishermen. I asked them in which area and at which depth they usually fished. In addition I integrated the data with my personal observations. A semi-quantitative map has been elaborated, according to the fishing techniques (Figure 45). Traps and nets are the most common gears used around the island between 0 and 50 meters, probably due to the occurrence of a dense belt of *Posidonia oceanica* and its role of nursery for many fishes of economic relevance. The pressure of traps and nets around the island is high almost everywhere, except locally, where the occurrence of shallow rocks can be dangerous for the integrity of gears.

In literature, data on fishing traps are scant for the Gulf of Naples where it is a very common gear, mainly to catch the cephalopod *Octopus vulgaris*. Around the island of Ischia, this activity is widespread and non-stop deployed, with a very large number of traps per boat. These fishermen spend most of the time standing and catching into the sea; they collect for each haul 200-300 traps, but many gears persist many times into the sea before to be hauled (pers. obs.).

Nets and fishing traps are potentially very dangerous because they can damage sea organisms thriving between 0-50 m, a bathymetric range in which trawling is forbidden. As we frequently found during SCUBA diving surveys the occurrence of fish nets and lines (ghost gears), often strictly interlaced with benthic specimens, we tried to estimate their pressure (Figure 46). The highest impact has been recorded in the Sector C; less but in any case high pressure along the south coasts of the Ischia Island and on banks have been detected (Table 7).

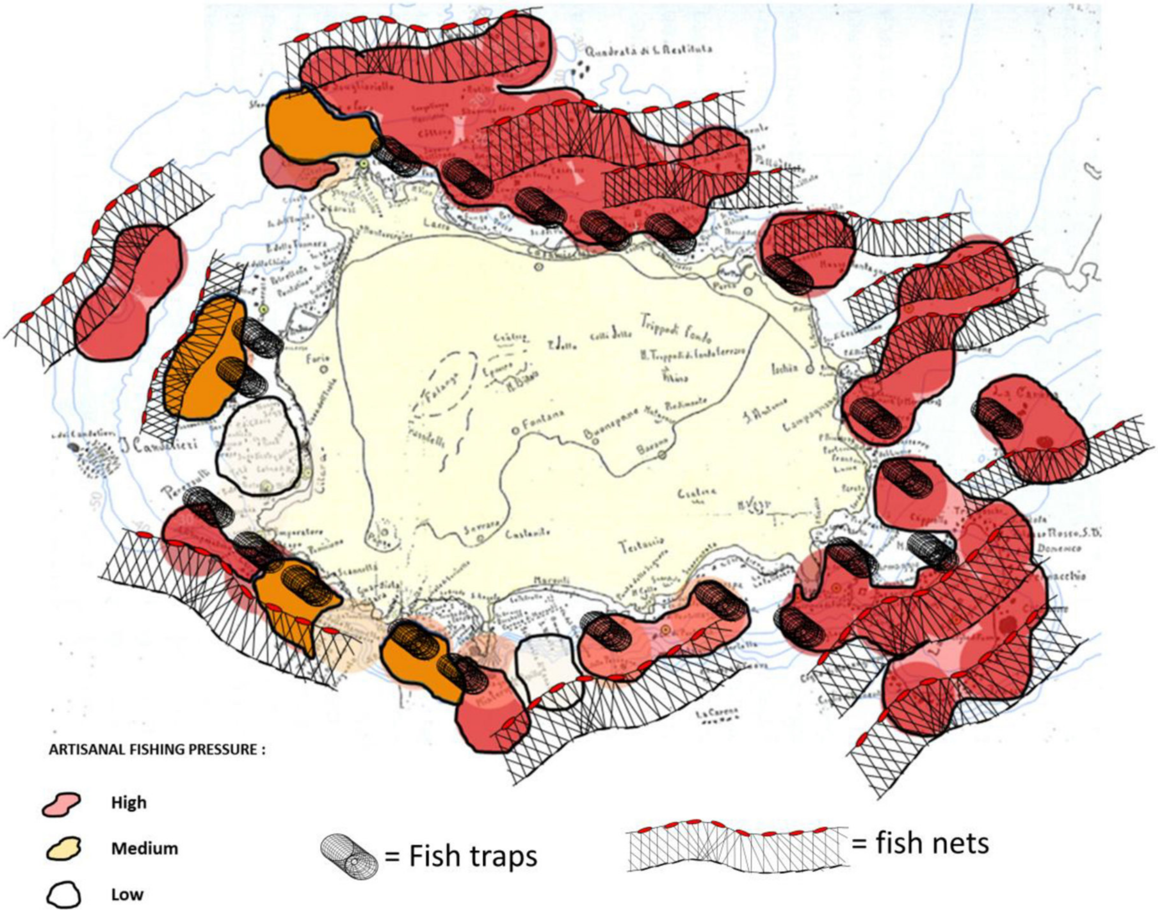


Figure 45: A semi quantitative map of the current artisanal fishing efforts around the island of Ischia

Table 7: Signals of fishing pressure valuated in some localities of the gulf during S.C.U.B.A. diving activities (the number of '+' indicates the abundance class: none=absent, +=very rare, ++=rare, +++=common, ++++=very abundant; DMH= date mussel harvesting)

Sector		Survey site	Fishing pressure
A	**Phlegrean Islands**	Banco d'Ischia	++++
		Bell'Ommo	++
		Capo Grosso	+++
		Formiche	++
		Il Faraglione	
		La Nave	++++
		Secca di Forio	++++
		Le Camerate	
		Pietra Nera	
		Pietra Bianca	
		Procida	++++
		Punta Imperatore	
		Punta Spaccarello	
		S. Angelo	+
		San Pancrazio	+++
		Scannella	++
		Scannella Deep	
		Secca del Santuario	+++
		Secca Lacco Ameno	+
B	**Bay of Pozzuoli**	Capo Miseno	++++
		Miseno est	++++
		Baia	+
C	**Bay of Naples**	Marechiaro	++++
		Casa degli Spiriti	++++
		Nisida	++++
		Secca della Badessa	++++
		Secca della Cavallara	+++
		Secca di S. Giovanni a Teduccio	++
		Secca di Torre Annunziata	+++
		Capo Posillipo	+
		Rocce verdi	+
		Nisida	++

		Porto Paone	
		Santa Lucia	
		S. Croce	
D	**Sorrento Peninsula**	Vervece Madonnina	**++ DMH**
		Cala di Mitigliano	
		Punta Campanella	**+**
		Capo di Massa - Puolo	**++ DMH**
		Secca del Vervece	**++ DMH**
E	**Capri**	Bagni Tiberio	
		Punta Carena	
		Punta del Capo	
		Punta dell’Arcera	
		Scoglio della Ricotta	

Mechanical damage of marine debris (with the distinction between covering and abrading debris) has been evaluated in different Italian regions (Campania, Sicily and Sardinia). According to this classification, the highest mean value of debris abundance was found in Campania in deep habitats (0.12 debris/m^2, ranging from 0.02 to 0.16 debris/m^2) compared to Sicily and Sardinia (Figure 47) (Angiolillo et al., 2015; Bavestrello et al., 2014; Bo et al., 2014). All these data support the high pressure of fishing activity in the Gulf of Naples.

Figure 46: Records of fishing gears and longlines interlaced with macrophytes and sea fans (the last photo on the right comes from Simeone et al., 2010)

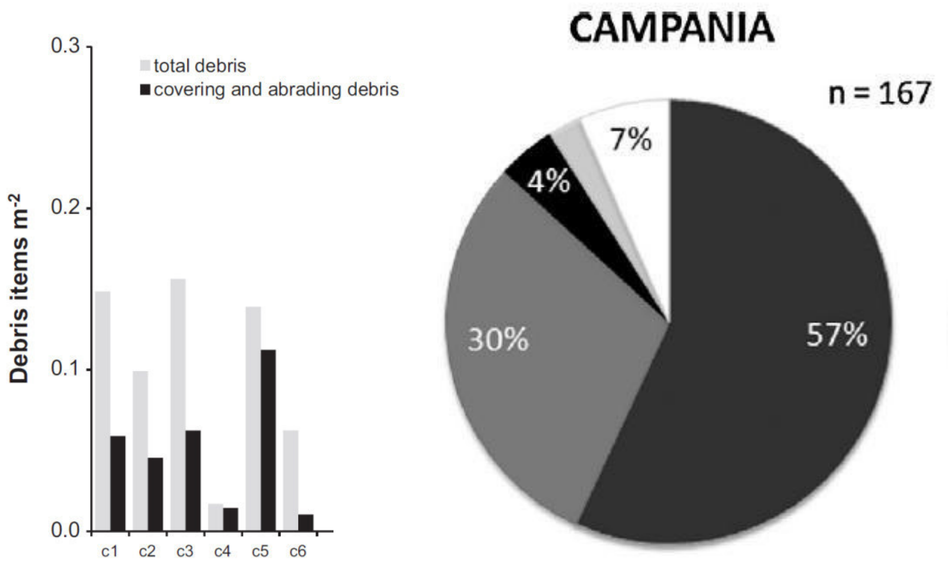


Figure 47: Frequency of occurrence of marine debris items found in the Gulf of Naples (Amalfi coast included); c1: Amalfi, c2: Li Galli; c3: Nisida, c4: Ischia1, c5: Ischia 2; c6: Procida (from Angiolillo et al., 2015, modified)

Some interesting data on the occurrence of *Cystoseira* or *Sargassum* spp. came out by my query to fishermen. Some of them confirmed to find (at least in the past) in their nets branched brown macroalgae, especially *Sargassum* spp., historically used to maintain fresh and fragrant the catch for their good smell ('*Fa addoventà i pesci marci, fritti*').

Along the coasts of the gulf, other non-commercial fishing activities such as *Mytilus galloprovincialis* harvesting and *Eriphia verrrucosa* fishery ('Rancio Fellone') can interact with the occurrence of fucoids in the shallowest fringe causing harvesting disturbance and trampling activity. Both these activities are very frequent in the following sectors: A (Procida, Vivara), B (Pozzuoli), C (Gaiola, Posillipo, Torre del Greco, Ercolano, and Portici).

An unexpected output came from my monitoring program around the coasts of Capri, where the records of *M. galloprovincials* were very rare and no harvesting activity was detected. During spring-early summer time, the locals keep clean any moorings and harbour walls in order to avoid mussel settlement. In this manner the spread of this species is very low.

In the past times sampling for scientific purposes in the gulf was widespread and Lo Bianco (1909) reported that some banks close to Naples city were abandoned by fishermen and collectors of the Stazione Zoologica because of the loss of species of interest, it is unclear if it was due a deterioration of environmental quality, overfishing or oversampling, or finally a combination of these. However, the magnitude of the impacts performed by collectors on benthic communities should be considered as secondary percentage respect to fishing activities that in the past were frequent also in shallow depth (trawl fishery; especially beam trawl, otter trawl and traditional fish gear such as ingegno or gangamo, angamo, vangaiola, gangui) for the collection of fish, red coral and sponges (Costa, 1870; Mazzarelli & Mazzarelli, 1918; Colantoni et al., 1982; Langella, 2011; Fleet Register, 2012). For these reasons is strongly unlikely that the collection for research activity played a leading role in Fucales depletion.

We have to remember that the Neapolitan area is famous all around the world for its handmade shell cameos and coral jewels. Some coral factories as well as Capodimonte porcelains are listed in Lonely Planet books. This economy has deeply impacted the local populations of corals. Deep banks of red coral (*Corallium rubrum*) were historically present in many shoal all along the gulf (Mazzarelli & Mazzarelli, 1918), but the recent review of the sites conducted by Bavestrello et al. (2014) revealed a high percentage of dead colonies, almost totally collapsed because of heavy overfishing occurred during the 19th and 20th centuries, by both trawling gears and scuba diving. Healthy populations are still present only along Phlegrean Islands (Figure 48).

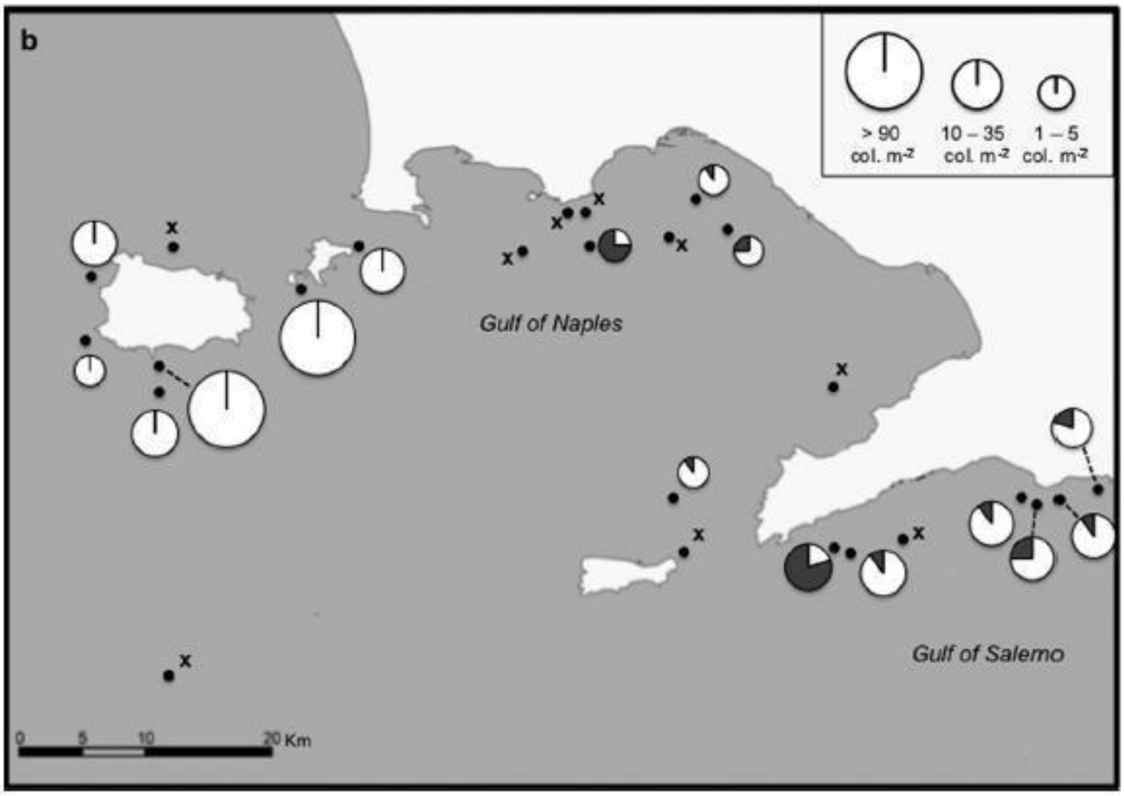


Figure 48: Healthy colonies of *C. rubrum* (white circles), dead colonies (black) and loss (x) (Bavestrello et al., 2014)

To conclude this paragraph, the pressure of aquaculture has to be taken into account too. According to Carillo et al. (2008), in 2003, 43 aquaculture plants (36 mussel and 7 fish farms, respectively) were recorded in Campania region. The occurrence of the 13 mussel farms in the gulf are reported in Figure 49. They are settled at Baia, Bacoli and Capo Miseno in the Sector B, and at Nisida, Castello dell'Ovo, Ercolano and Castellamare di Stabia for the Sector C. Results from previous studies of their impacts on the benthic communities have provided positive, no, or negative effects (Neofitou et al., 2014, and references therein). Up to now, there are no local data to evaluate and quantify the effects on benthic communities in the study area.

Figure 49: Occurrence of mussel farms (*Mytilus galloprovincialis*) in the study area

2.4 Conclusions

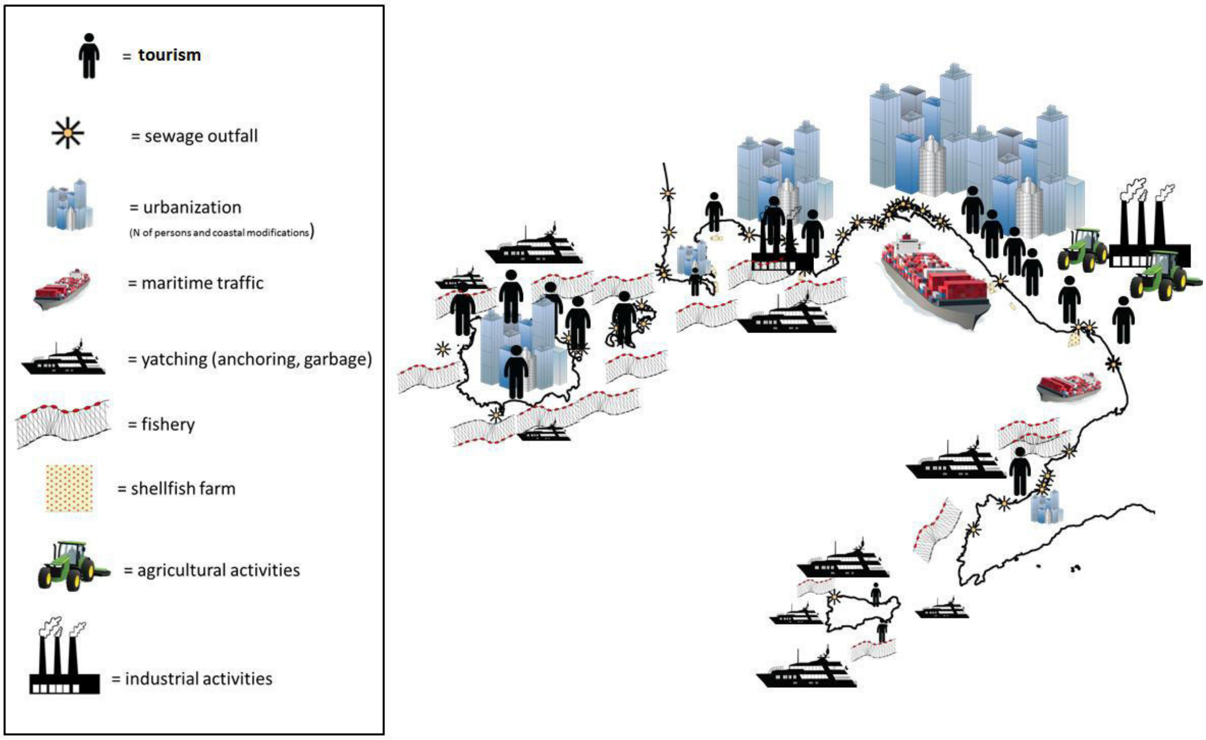


Figure 50: Summary of cumulative impacts in the Gulf of Naples

In the first chapter of this thesis a general survey of the main threats affecting the distribution and abundance worldwide of fucoid species has been presented. Based on these results, historical and current knowledge on human activities and pressures have been reviewed and analysed in different sectors of the island focusing the attention mainly on those that can represent a threat for habitat forming species such as seagrasses and fucoid algae (Figure 50).

Summarizing:

1. Urbanization, sewage outfall, fishery and maritime traffic represent the principal stressors in the region for fucoids.

2. The Gulf of Naples is an internationally renowned touristic location, not only for its historical attractions, but also for swimming and leisure activities along the coastline and the islands, especially in the summer months. Tourism supported the development of local

infrastructure and services and represents a major source of income and employment, but can also lead to negative impacts such as coastal destruction and discharges into the sea.

3. One third of the entire coastline of the gulf is artificialized (34%). About 20% is localized on the metropolitan area (Sector C) including the large harbour area (one of the most important of the Mediterranean Sea); Pozzuoli Bay (Sector B) with its ex-industrial area and Ischia (northern side) (Sector A) have a quite similar loss of natural coastline (8 and 6% respectively).

4. The gulf is not totally covered by a sewage system plan, capable to support the high density of population (Sector B and C), and to guarantee the huge tourism in summer time (Sector A).

5. Discharges of non-treated or without appropriate depuration sewage are still widespread along the region (in all sectors).

6. Although focused legislations exist (i.e. DL 11.05.99 Nr. 52 to safe the water quality), their compliance is not provided (i.e. Sector A).

7. Maritime traffic is severe during the summer time; there is no control on anchoring, particularly where there are restrictions (Sector A), where a MPA has been established

8. Reserve effects for MPA have not been evaluated (but Sector D) but the level of their enforcement is strictly related to the extension of the MPA and to the number of people engaged. In the study area, for most of the protected surface, MPAs can be considered ‘paper park’.

9. Pressure of fishing activity in different sectors is poorly documented for the entire gulf. The unique available data are the fishing vessels registered in the gulf through the Fleet Register, but represent a high underestimation, especially for those gears that are performed by artisanal fishery (gill nets). Semi-quantitative data obtained for this category

at Ischia Island testify a high pressure all around the island, where *Posidonia oceanica* meadows occurs, with different techniques. No historical data exist both on the amount/quality of the fishes and the real number of operating fishing vessels and where they operate: therefore it is impossible to detect the pressures or evaluate the impacts.

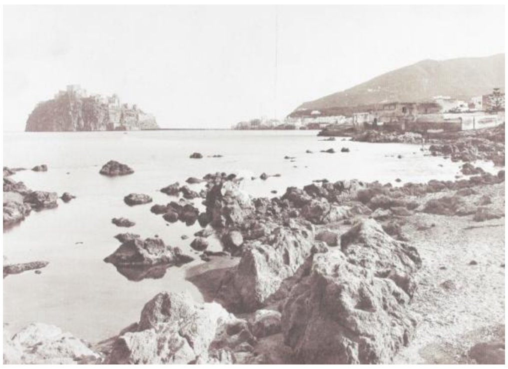
In general we can conclude pointing out the most relevant gaps:

- only data about the locations at which many threats occur are available but without measure of their extension, intensity and state
- information are scattered in space and time
- the contemporaneousness between a biological status and pressure is lacking and it makes difficult to strictly relate an effect to a putative cause
- a baseline is needed

Consequently, the analysis, maintenance and improvement of the quality of the marine environment in the gulf are major issues not only for social and economic reasons, but also for the welfare of the entire ecosystem.

3. Historical changes of Fucales in the Gulf of Naples






3.1 Introduction

There is no doubt that humans exerted many pressures on marine ecosystems since ancient times; these pressures induced deep seascapes changes that are today not questionable. In Mediterranean Sea, for instance, human activities have influenced and changed the abundance of marine resources since at least Roman times and accelerated in the XIX and XX centuries (Lotze et al., 2011). Over time, such modifications have altered the abundance of many assemblages, the structure and functioning of marine ecosystems (Pauly, 1995; Jackson, 1997; 2001). However, to fully understand the current state of marine ecosystems, we need to know their long-term history in order to detect any changes respect to their pristine state (Lotze & McClenachan, 2014).

Long Term Ecological Research Program (LTER) initiated a new era in time-series investigations. Time-series observations have been a core strategy in oceanography for more than fifty years (Ducklow et al., 2009). Since 1977, the National Science Foundation (USA) supported with emphasis ecological researches that require long time period and large spatial scales (Callahan, 1984). Since the establishment of the International Long-term Ecological Research network (ILTER) in 1993, global long-term ecological research programs expanded rapidly, reflecting the increased appreciation towards the conduction of research on ecological issues that can last decades and span huge geographical areas. Actually, sub-networks were adopted in Europe (LTER-Europe) and considered in Italy since the end of 1990s, being official in 2006 (LTER-Italy).

Marine historical ecology is a relatively recent multidisciplinary and emerging research field, aiming to reconstruct past ecosystems and their changes. Pauly (1995) referred to this historical change in fishery ecology as sort of amnesia, the ‘shifting baseline syndrome’ or the paucity of pristine ocean as a reference point, a widely relevant concept for each ecosystem. So every one of us, referring to the perceived as normal status of an ecosystem, is used to think that the desirable and acceptable condition of the sea is the state we experienced in our life span. This contributed to a shift in our perception of what is natural toward more and more degraded ecosystems. In this way, things that we think as natural today, such as the abundance or size of a biological resource (e.g. fish), may be drastically different from what our parents and grandparents perceived.

Most studies in marine historical ecology have focused on single species or a charismatic group (e.g. mammals, turtles) and a single human pressure (Lotze & Worm, 2009 and reference therein). Others have analysed historical changes across several taxonomic or functional groups due to multiple human pressures in different geographical areas (Pandolfi et al., 2003; Lotze &Worm, 2009; Harnik et al., 2012).

The Mediterranean Sea has been strongly influenced by human activities for millennia. Although the historical ecology of its surrounding terrestrial ecosystems has received extensive consideration, historical changes in its marine ecosystem are less known (Lotze et al., 2011; Ferretti et al., 2013), especially concerning the ecosystem engineer brown macroalgae (Thibaut et al. 2005; Falace et al., 2010). Historical records (HR, hereafter) in phycological studies represent a valuable reference line to detect and understand changes in ecosystems and therefore for the assessment of their current status. However these data can be scarcely available especially in marine benthic vegetated systems due to frequent unavailability of suitable and detailed historical records, lack of taxonomic expertise and logistical difficulty of conducting regularly repeated surveys in wide areas.

Broad scale marine investigation has started from the 60s and lead to a sea exploration by a high number of S.C.U.B.A. divers since 30-40 years. In this period, S.C.U.B.A diving became a leisure activity and popular sport in Mediterranean Sea, leading also to an increase of scientific publications in marine biology and studies directly linked with the *in situ* sampling/manipulative experiments.

Studies on marine species in the Gulf of Naples started at the end of the 1800 since the foundation of the research institute Stazione Zoologica di Napoli (SZN), in 1872. Even if a temporal discontinuity among data occurred, the most valuable and complete contribution on marine algae recorded in the Gulf of Naples was given by the Prussian phycologist Georg Valentine Funk (Figure 51) in the time interval 1900-1955, as he spent at the SZN a span of 47 years (Buia & Groeben, 1999). He therefore strongly contributed to create a solid reference line to detect following changes in the coastal benthic vegetation. Invaluable historical interest has the first monograph (Funk, 1927), where he reported the popular names used by fishermen of the gulf. For instance, "Valiante's plant" was used to indicate *Cystoseira* spp., in order to remember Raffaello Valiante the researcher who described the variety of species in the gulf (Valiante, 1883). Funk fishermen used popular names also to distinguish different Fucales: the species called as 'Valiante's plant of high depth' *(Cystoseira e' profondità)* was *C. spinosa*; the Valiante's plant with olive fruits (*Cystoseira a frutta d'olive)* corresponded to *C. zosteroides*, while with the term 'herbs with lices' (*erva cu 'e perucchie)* they usually indicated *Sargassum acinarium* (Funk, 1927, 1955). In Posillipo ancient fishermen called these species 'Scienza' (Simeone pers. comm.;

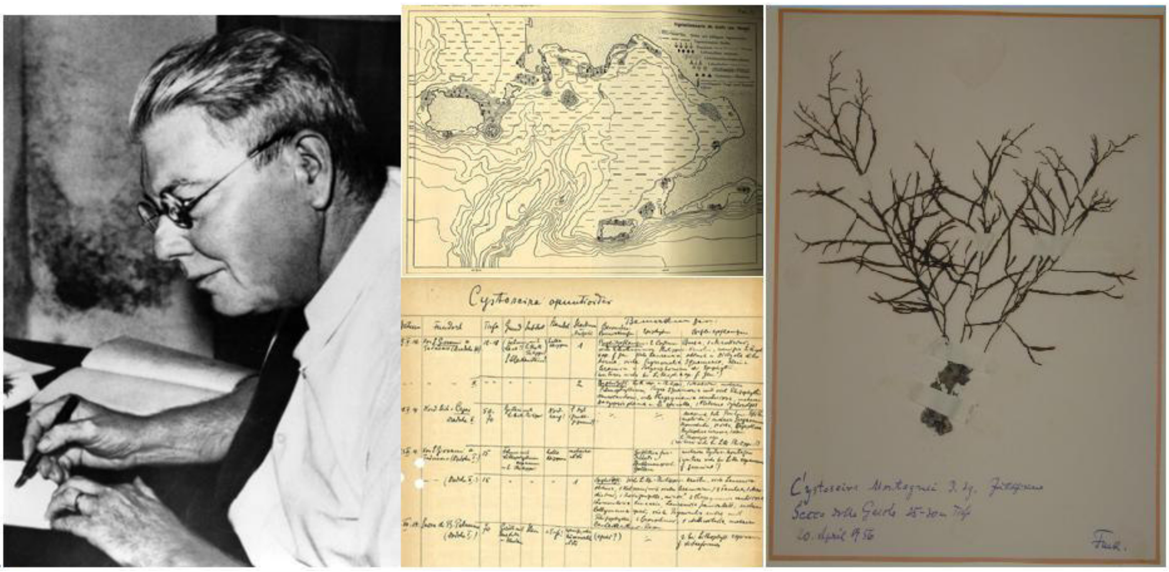


Figure 51 : Georg Funk at work, his map with the distribution of *Cystoseira* specimens in the gulf, a page of his diary and a voucher from his herbarium (Georg Funk picture: courtesy of Universitäts Bibliothek Giessen, Germany).

the term literally translated is 'Science'). The origin of this old term is unknown, but it could be hypothesized that fishermen meant this word as 'wanted by scientists of SZN'.

In Lo Bianco (1909) and the SZN Zoological Collection, *Cystoseira* and *Sargassum* frequently represented the substrate on which organisms (i.e. caprellids, sponges and hydroids) were preserved. Moreover, there are also paratypes of isopods and polychaetes described and reported in the Gulf of Naples which have been collected on the frond of fucalean species.

The old sampling methods were rarely listed by the authors, but we can gather some information thanks to the Funk's monography (1927). The samples were generally collected by sight with manual devices (until 5 metres depth), by nets (i.e. gangamella, strascico) towed by rowing boats (until 20 m depth) and with mechanical trawling or purse seine (until 100 depth, the vegetation boundary of the gulf).

In order to evaluate the current status of *Cystoseira* and *Sargassum* spp. in the Gulf of Naples, I gathered all available data cited in the literature (peer-reviewed academic journals, grey literature, herbarium vouchers, preserved samples, private collections and old/recent photos from underwater photographers) searching any records of Fucales algae in the study area.

Afterwards, cited sites have been revisited in order to detect the current occurrence, any change in the distribution and finally detect the current status of fucoids in the gulf.

3.2 Material and methods

3.2.1 Study site

The Gulf of Naples is located in the Tyrrhenian Sea, central Mediterranean Sea, along the south western coast of Italy (Campania region). It is 870 km² wide and about 200 km long with an average depth of 170 m. Geographically the study area, ranges from the Phlegrean peninsula on the north-west (the islands of Ischia and Procida, the north campanian coast from Isolotto di San Martino) to Sorrento Peninsula (Punta Campanella on the south), including the island of Capri (Figure 52). These two extremes of the gulf are characterized by different geological nature: volcanic the first and calcareous the last one; the coast is mainly rocky with some sedimentary beaches. The Bay of Pozzuoli and the Bay of Naples, separated by the Posillipo promontory, are further distinguished.

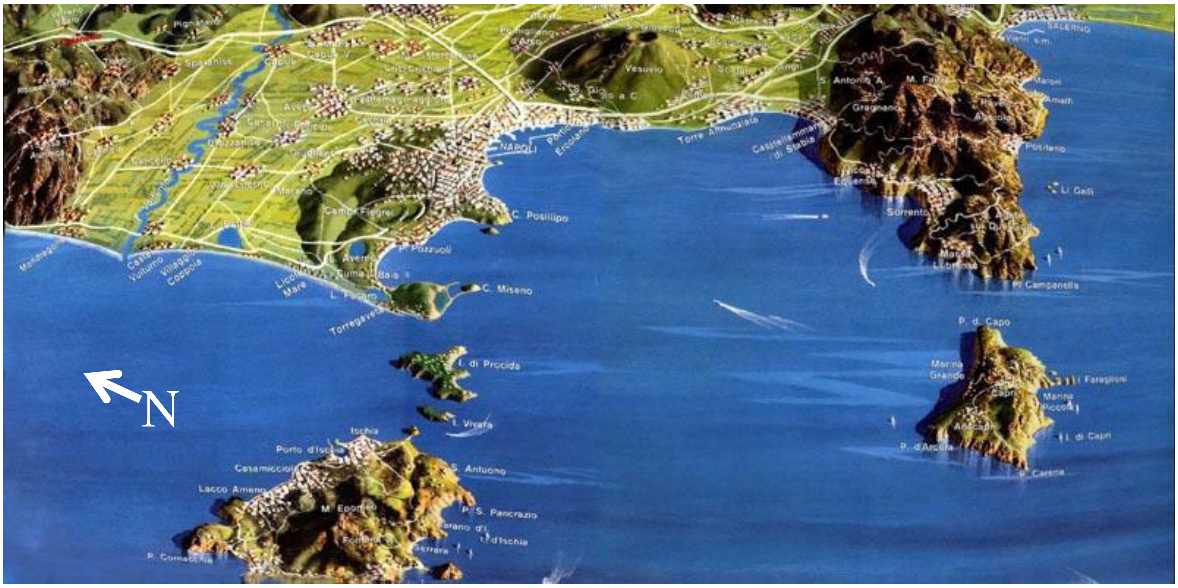


Figure 52: The study area, the Gulf of Naples (from http://fantasticpixcool.com/)

The area, inhabited in Pre-Roman times, is one of the oldest settlement continuously inhabited and is currently occupied by about 4 million of people reaching exceptional densities, comparable in some sites to an Asian megalopolis (i.e. Portici city: 12,000 inh/km2) (Istat, 2013). In the centre of the town of Naples is located the harbour that, covering an area of 12,000m^2, is one of the largest sea harbour in the Mediterranean sea and has the world's second-highest level of passenger flux, after the port of Hong Kong. In fact, the gulf represents one of the favourite destinations for tourism thanks to its artistic and archaeological interests and natural beauty: an example is given by the Ischia Island (the largest among Phlegrean Islands), with about 4 million travellers per year (http://www.ischiamarket.com/informazioni-ischia.php).

3.2.2 Data collection

There is a considerable amount of historical data dealing with the occurrence of macroalgae in the gulf, since the end of nineteenth century. This period was coincided to the foundation of the Stazione Zoologica Anton Dohrn of Naples, in 1873. The center was at that time the first independent research facility for marine biologists from all over the world.

In order to detect any previous records of Fucales in the Gulf of Naples, peer reviewed articles, technical reports, thesis, herbarium vouchers and preserved samples were carefully analysed. In particular, referring to the Index Herbariorum website (http://sweetgum.nybg.org/science/ih/; Thiers, 2014), a list of all the Italian herbaria was prepared (Table 8) and the occurrence of *Cystoseira* and *Sargassum* spp. vouchers collected from the Gulf of Naples were considered and queried to their curators.

Table 8: Queried Italian Herbaria

Herbarium Anconitanum – Dip. Sci. Agrarie, Alimentari ed Ambientali, Univ. Marche (**ANC**);
Herbarium Horti Botanici Barensis - Istituto Ortobotanico, Univ. Bari (**BI**);
Erbario e Museo Botanico - Sistema Museale d'Ateneo, Univ. Bologna (**BOLO);**
Erbario Istituto ed Orto Botanico - Seaweeds Herbarium, Univ. Catania (**CAT**);
Herbarium Universitatis Florentinae - Natural History Museum, Univ. Firenze (**FI**);
Herbarium Messanaensis – Dip.o di Scienze Biologiche ed Ambientali, Univ. Messina (**MS);**
Herbarium Universitatis Mediolanensis-HbMI – Dip. Biologia, Univ. Milano (**MI);**
Hortus Botanicus Mutinensis- Univ. Modena e Reggio Emilia (**MOD**);
Herbarium Neapolitanum – Dip. di Biologia Vegetale, Univ. Napoli Federico II (**NAP**);
Herbarium Patavinum - Centro Interdipartimentale Musei Scientifici, Univ. Padova (**PAD**);
Herbarium Mediterraneum Panormitanum – Dip. Biol. Ambientale Biod. Univ. Palermo (**PAL**);
Erbario Orto Botanico – Dip. Biologia Evolutiva e Funzionale, Univ. Parma (**PARMA**);
Herbarium Universitatis Ticinensis - Dip. Scienze Terra e dell'Ambiente, Univ Pavia (**PAV**);
Erbario – Dip. Biologia vegetale Università di Perugia (**PERU**);
Herbarium Horti Pisani – Dip. di Biologia, Museo Botanico, Univ. Pisa (**PI**);
Erbario Patologico "Alessandro Trotter", Portici (Napoli) (**POR**);
Museo Erbario - Dipartimento di Biologia vegetale, Univ. Roma La Sapienza (**RO**);
Erbario –Dip. Botanica ed Ecologia Vegetale, Univ. Sassari (**SS**);
Erbario Talassografico "A. Cerruti" - Istituto per l'Ambiente Marino Costiero – CNR (**TAR**);
Herbarium Universitatis Taurinensis – Dip. Biologia Vegetale, Univ. Torino (**TO**);
Erbario, Algarium, Nova Colletio Corallinales - Dip Scienze della Vita, Univ. Trieste (**TSB**);
New Herbarium - Museo di Storia Naturale di Venezia (**MCVE**).

I also examined and queried the Macro-algal Herbarium Portal (http://macroalgae.org/portal/collections/listtabledisplay.php?usecookies=false&starr={%22taxa%22:%22Sargassaceae%22,%22usethes%22:true,%22taxontype%22:%221%22,%22country%22:%22Italy%22}&jsoncollstarr={%22db%22:%22allspec%22}).

Moreover, I analysed historical herbaria of Funk, Berthold and anonymous collectors (not yet indexed) together with the dried vouchers and wet samples of the SZN Herbarium kept at Villa Dohrn Ischia-Benthic Ecology Lab.

The quality of specimens depended on the age and conservation status of the vouchers; however the spatial and temporal references of data collection were not always reported. In this last case the record has not been taken into account. When no taxonomic identification occurred or misidentified specimens were present, I personally identified the voucher.

I georeferenced (with the maximum possible accuracy) all the records to a GIS database in order to have an overall but detailed information per each sector. If not possible (for example when a voucher note just stated 'Capri Island'), I spatially represented the record in the database I realized, exactly at the center of the island, or I specified in the database notes this information. During the data collection I also gathered many HR with low taxonomic resolution (*Cystoseira* sp., *Sargassum* sp.). Despite the low taxonomical level, even these data have been analysed and discussed, being important evidence of these genera in the HS.

I divided all records by bathymetric intervals (shallow=0-5 m; deep= deeper that 5 m); for depths deeper than 40-50 m we didn’t directly surveyed the sites, but we assessed by means of ROV videos analysis or video from professional technical divers.

3.2.3 Re-survey of historical sites (HS)

Sites where *Cystoseira* and *Sargassum* spp. were historically recorded were re-surveyed from the past in order to detect any temporal changes. 'The number of re-survey per each site varied from at least 1 time to a maximum of 3 times, depending on the interest of the site and sea floor heterogeneity.

In order to evaluate the current occurrence of the species previously found, I re-surveyed the historical sites (HS) from Isolotto di San Martino (40.799065° N; 14.036389° E) to Punta Campanella (40.568866° N; 14.325040° E) including all the islands of the gulf. For the shallow records (from 0 to 5 m), I both snorkelled and used a 4.85 m long kayak to reach HS, moving very close to the coast. The kayak was also equipped with a handmade bathy-scope to detect the occurrence of target species below the water mark (Figure 53).

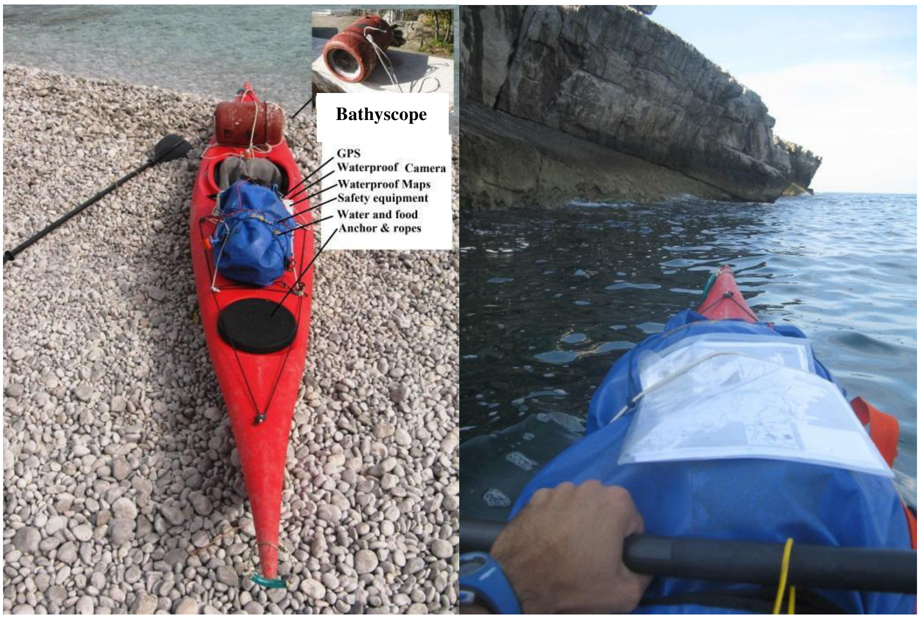


Figure 53: Materials used during the kayak surveys

Deep sites (from 5 to 50m depth) have been surveyed by S.C.U.B.A. diving during *ad hoc* SZN surveys for Phlegrean Islands; staff of diving clubs and Marine Protected Areas (MPAs) helped me in the other sectors of the gulf. For records deeper than 50 m depth, ROV data (videos and photos) of the gulf were analysed (‘Campagna Corallo Rosso 2010-2012’; Bavestrello et al., 2014, Angiolillo et al., 2015). For few HS deeper than 40 m and without ROV video availability (i.e. Bocca Piccola: depth 50-90 m), we only analysed video data gathered from the *ad hoc* Citizen Science project ‘Progetto Fucales’.

I based my surveys overlaying old and current maps (geological and bathymetric maps, Digital Terrain Models) from sea surface down to 40-60 m to identify suitable substrates, i.e. rocky reefs, coralligenous assemblages and detritic bottoms (Cervera, 1955; Colantoni et al., 1982; Gambi et al., 2003b; Nautical Chart n° 10, n° 129 Istituto Idrografico Marina; De Alteriis et al., 2006; Simeone et al., 2016a,b) (Figure 54, Figure 55, Figure 56,). Many historical records referred to shoals and banks were difficult to localize, especially when the sites were labelled with unofficial old fishermen names. For these sites the contributions of Lo Bianco (1909), Mazzarelli (1918), Miraglia (1941), Cervera, (1955) (Figure 56), Bacci (1946) (Figure 57) and Cognetti & Santarelli (1960) have been of valuable interest.

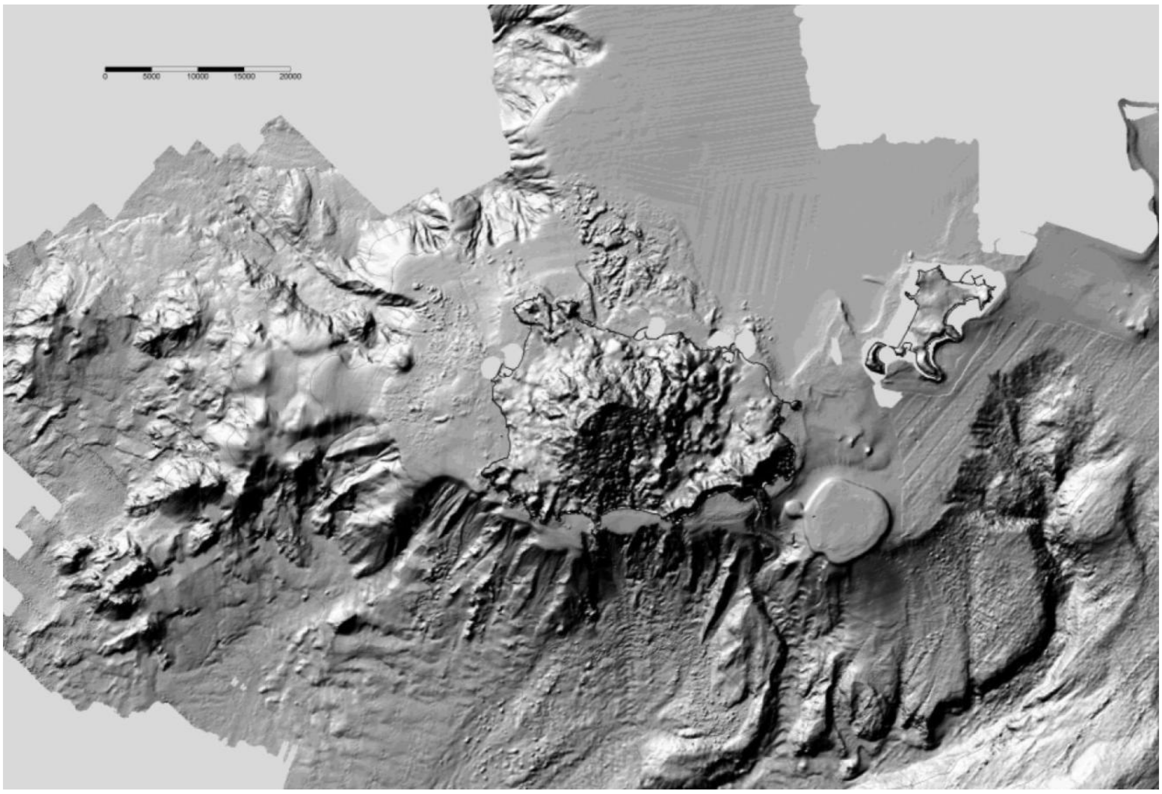


Figure 54: Digital terrain model (DTM) of Phlegrean Island (De Alteriis et al., 2006)

Generally, in many sites (especially around the Phlegrean Islands) the sea bottom from the surface to 30-40 m depth was colonized by *Posidonia oceanica* (intensely investigated by the researchers of the SZN since the end of 1970, Figure 55) (Colantoni et al., 1982; Gambi et al., 2003a; Zupo et al., 2006a,b).

I studied nautical charts, touristic maps (current and ancient ones) to be familiar with the places and the old name of quoted sites, with current ones: this information was acquired also by interviews with old local folks taking advantage of local ecological knowledge.

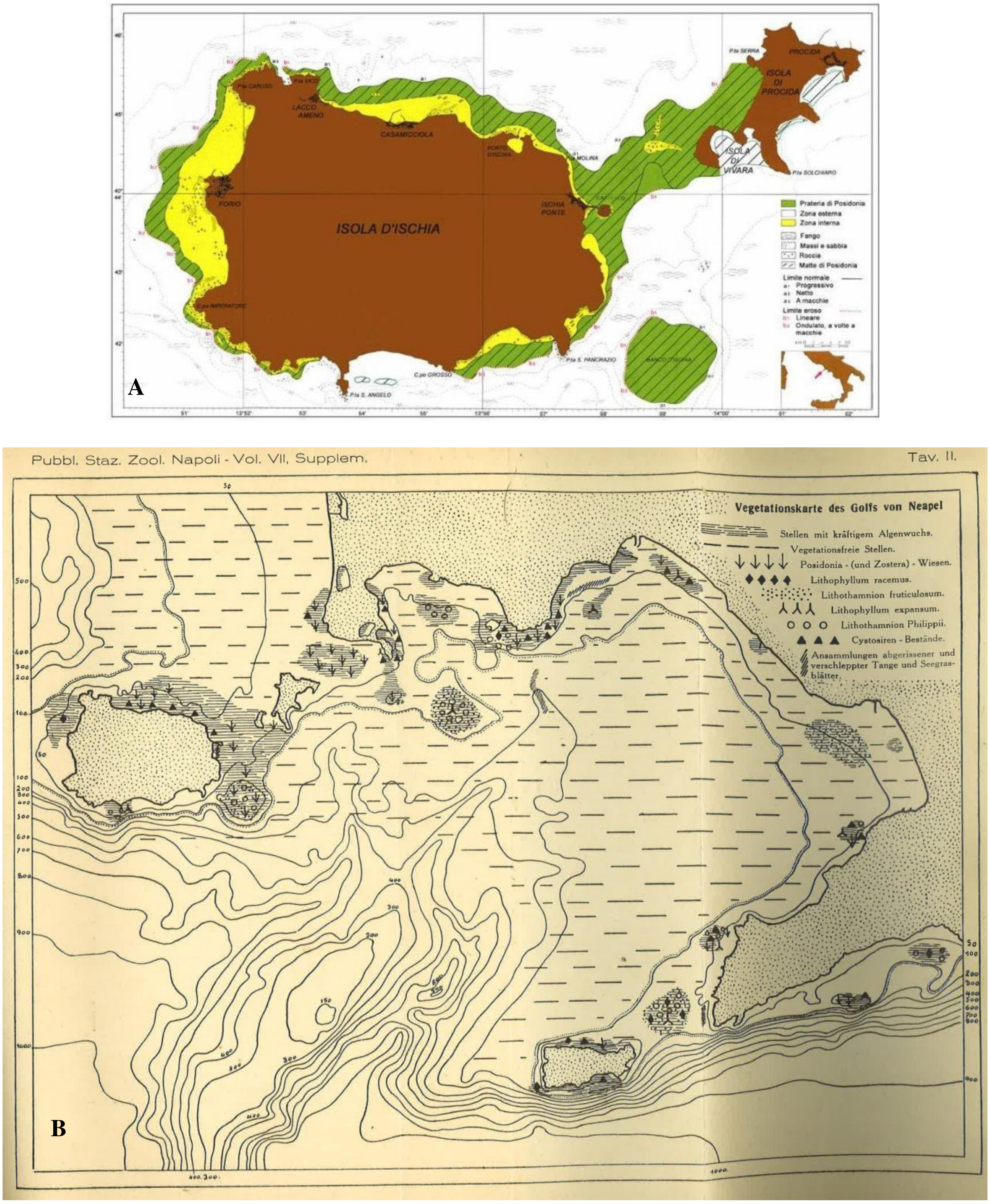


Figure 55: Map of *Posidonia oceanica* distribution all around the island of Ischia (A; Colantoni et al., 1982). Vegetational map of the gulf (B; Funk, 1927)

Figure 56 : Map of fishermen shoals and banks (Cervera, 1955)

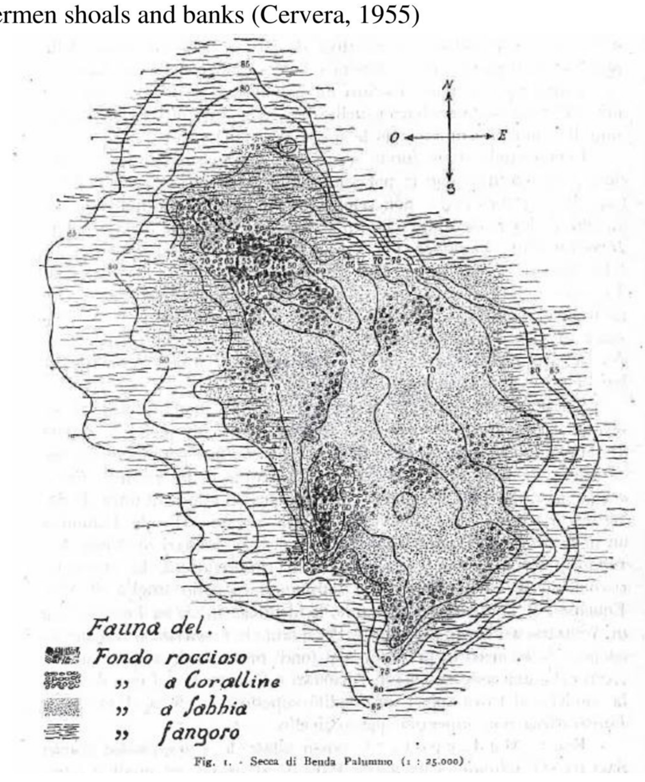


Figure 57: Banco di Biondo Palomba bank (commonly but incorrectly mentioned as Benta Palumbo or Penta Palummo by many past authors). The name came from the professional coral fisherman Biondo Palomba from Torre del Greco to whom his crew dedicated the bank (Bacci, 1946)

In addition a citizen science project 'Progetto *Fucales*: chi le ha viste?' (hereafter PF) was developed (Figure 58) in order to increase knowledge on the ecological relevance of Fucales and

Figure 58: The poster edited in the frame of the Citizen Science project 'Progetto Fucales: chi le ha viste?' addressed to all the marine stakeholders, with special interest of scuba divers, fishermen and kayakers

on their regression in the study area, involving local stakeholders (scuba divers, fishermen, kayakers).

Posters and pamphlets with pictures of the most simply identifiable species were produced and sent to MPAs and Scuba Diving Centres, mainly directed to photographers. In addition, the importance of these species were highlighted during public meetings (MPAs, Città della Scienza and Marevivo events).

The changes over time were summarized and analysed by a G.I.S. (Geographical Information System) database, realized with the open source software QGIS Wien (2.8.2 version). Bathymetry shape-files (10m intervals, UTM33 - WGS84) have been provided by National Research Council (CNR)-Istituto Ambiente Marino Costiero (IAMC) of Naples (D'Argenio et al., 2004). Basics Digital terrain Models (DTM) for the implementation of the database have been visualized (WMS) or downloaded from the web site of Italian Ministry of Environment (Geoportale Nazionale) and GIS Repository (http://www.pcn.minambiente.it/GN/accesso-ai-servizi/servizi-di-visualizzazione-wms. A complete list of historical sites is reported in Annex I, at the end of this thesis.

We compared the presence or absence of historical and current records in the gulf; in order to better understand local temporal changes in the richness and occurrence of *Cystoseira* and *Sargassum* species. The study area (Gulf of Naples) was furthermore subdivided in 5 smaller sectors: Phlegrean Islands **(A),** Bay of Pozzuoli (**B**), Naples Bay or Bay of Naples (**C**), Sorrento Peninsula **(D)**, and Capri Island **(E)**. The boundaries of this area, with the most relevant localities, are represented in Figure 59.

Changes over time were obtained comparing historical data with those obtained in the years 2013-2016. According to the number of historical sites (HS) in which the species was currently no longer found, the percentage of loss was calculated as the following established Loss Index (LI):

$$LI = \frac{\text{number of current absence in historical sites} \quad (HSCA)}{\text{total number of past occurrence} \quad (totHS)} \times 100$$

As it was a preliminary observation, we tried to hypothesize a possible trend of their temporal dynamics in the gulf. Based on the number of total historical sites, five classes of abundance were created. They were: absent (0); very rare (1-5); rare (6-10); common (16-30) and very common (over 21).

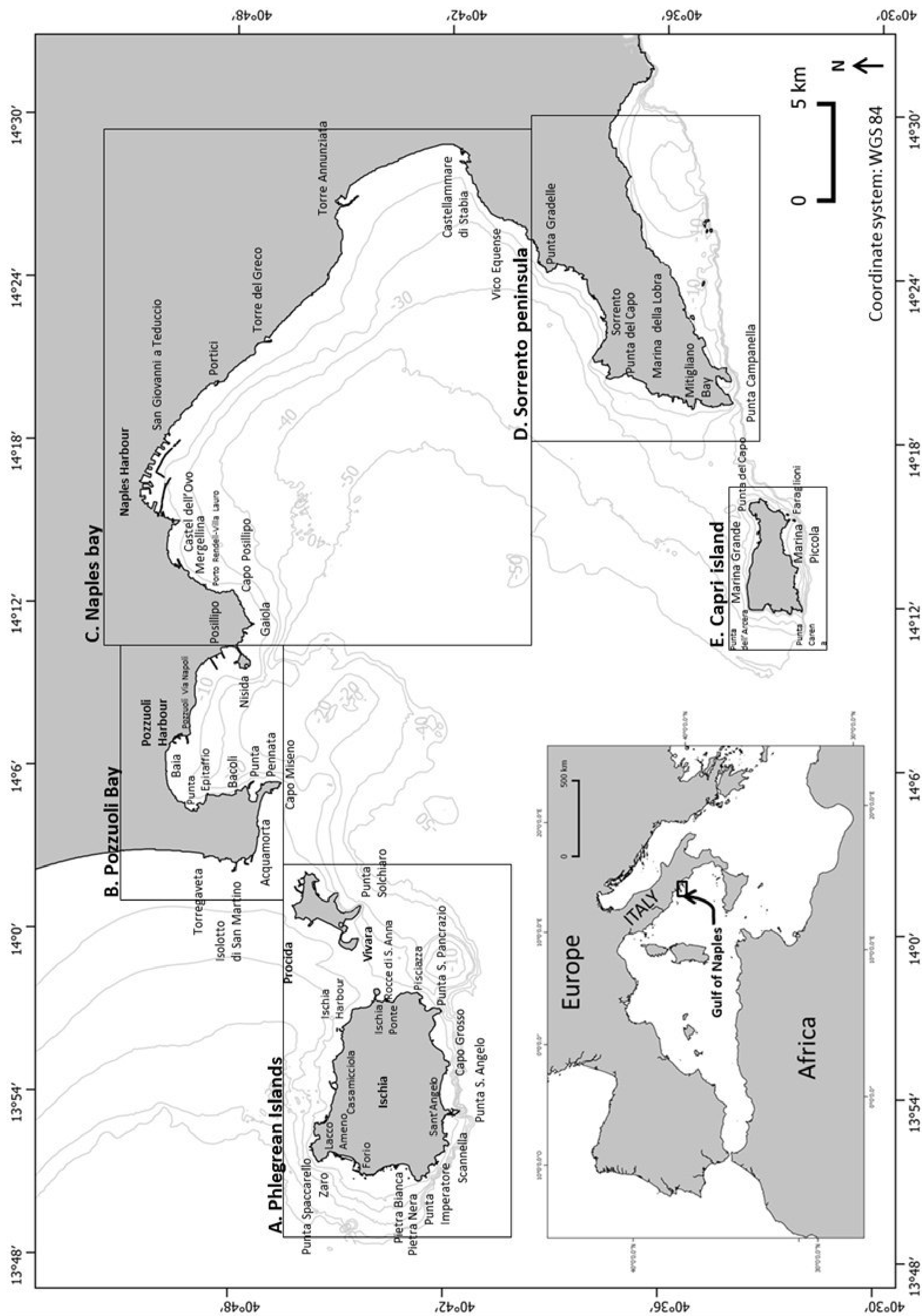


Figure 59: Different sectors in which the Gulf of Naples has been divided

3.3 Results

3.3.1 Historical data and 2013-2016 re-survey

There was a good amount of historical data available dealing with the occurrence of the *Cystoseira* and *Sargassum* genera in the Gulf of Naples. The source of data come from publications, books, monographies, voucher herbaria, preserved samples and some old photos of professional photographers in the framework of the developed citizen science project.

Vouchers held in herbaria were a powerful source of data providing a very good baseline for the historical change assessment and for future research.

The first hint to marine flora of the Gulf of Naples has to be referred to ‘Dell’ Historia Naturale’ by Imperato Ferrante (1589). Unfortunately ‘this collection moved to Domenico Cirillo and then lost in a fire hanged by the fury of the population at Sant'Antonio Abbate (Naples) in June 13, 1799’ as it has been reported by Balsamo (1892).

The first practical historical milestone comes from the valuable contribution of Delle Chiaje (1829): ‘Hydrophytologia Regni Neapolitani’, with detailed nice drawings (Figure 60A) and the sketches of Vincenzo Serino, one of the most valuable professional illustrators of SZN (Figure 60B).

Overall 376 historical records have been listed since the beginning of the 19th century by Delle Chiaje (1829), with collections by several authors that preserved voucher herbaria such as Valiante, Mazza, Lo Bianco, Funk, Falkenberg, and Leick. After the two Funk’s monographies (1927, 1955), the next collections are poorly represented by voucher herbaria and several studies were dedicated to very punctual research sites or with a lack in species resolution (Gamulin-Brida, 1965; Gamulin-Brida et al., 1967; Cinelli, 1971; Zupo & Buia, 2000).

Another complete broad scale survey was made by Ernst (1959) from Sorrento to Massa Lubrense in the southern part of Sorrento Peninsula. Ribera d'Alcalà & Russo (2001) made a survey of Capri Island biocenoses along 28 depth transects around the island, but in this publication there is a lack of important information on the species identification (the term *Cystoseira* sp. or *Sargassum* sp. is commonly reported as the highest level of identification).

A synthesis of all the georeferenced HR for the study area is reported in Figure 61.

Figure 60: Pictures of *Cystoseira* spp. and *Sargassum* spp. from Delle Chiaje (1829) (A). Vincenzo Serino's drawing of *Sargassum hornschuchii* (B) (beginning of 1900; Copyright Stazione Zoologica Anton Dohrn di Napoli – Archivio Storico, Coll. Ua.I.68)

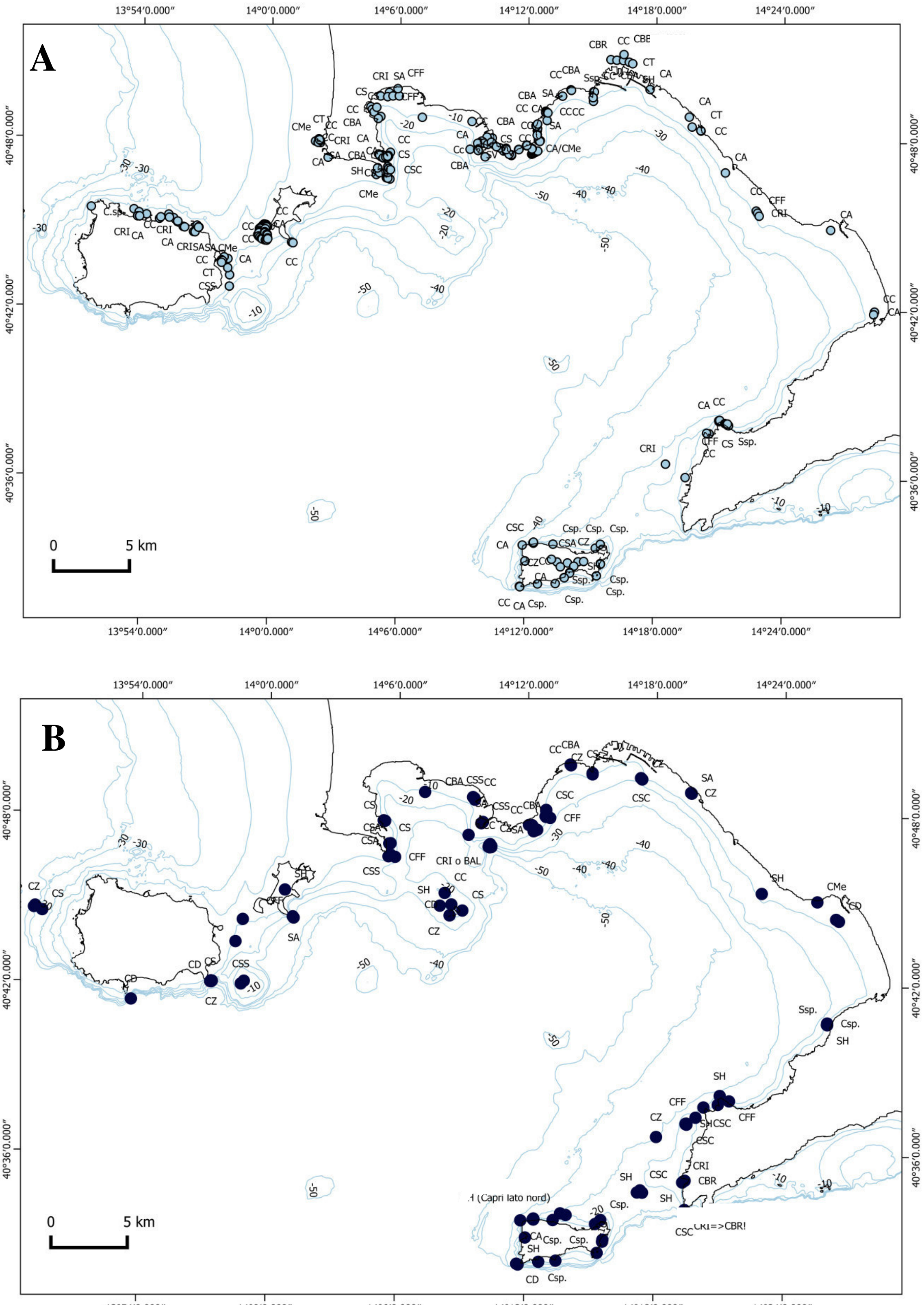


Figure 61: Map of the distribution of historical records (HR) of *Cystoseira* and *Sargassum* spp. in the Gulf of Naples (A: shallow HR; B: deep HR)

In the Annex I a list of Fucales historically recorded in the study area is reported; their taxonomic nomenclature has been updated according to Algaebase (Guiry & Guiry, 2016) and by Cormaci and Furnari (personal communications) in Table 9.

Table 9: Fucales recorded in the Gulf of Naples in the past, with the current taxonomically accepted name (Guiry and Guiry, 2016)

List of Fucales species		**Taxonomically accepted names**		**Code**
Cystoseira				
	amentacea	***Cystoseira***	***amentacea***	***CA***
	brachycarpa		***brachycarpa***	***CBR***
	hoppei or Hoppii		***barbata***	***CBA***
	barbatula		***barbatula***	***CBB***
	abrotanifolia		***compressa***	***CC***
	crinita		***crinita***	***CRI***
	fucoides		***dubia***	***CD***
	discors		***foeniculacea***	***CFF***
	funkii		***funkii***	***CFu***
	amentacea		***mediterranea***	***CMe***
	montagnei		***spinosa var. compressa***	***CSC***
	erica-marina		***spinosa var. spinosa***	***CSS***
	selaginoides		***sauvageauna***	***CSA***
	sedoides		***sedoides***	***CSE***
	ericoides		***tamariscifolia***	***CT***
	opuntioides		***zosteroides***	***CZ***
Sargassum				
	linifolium	***Sargassum***	***acinarum***	***SA***
	hornschuchii		***hornschuchii***	***SH***
	vulgare		***vulgare***	***SV***

Cystoseira amentacea (C. Agardh) Bory the Saint-Vincent

Cystoseira amentacea (CA, Figure 62) is widespread in the Mediterranean Sea. Two varieties are generally considered: *C. amentacea* var. *amentacea* and *C. amentacea* var. *stricta*, but they are poorly characterized and will not be distinguished here (Thibaut et al. 2015a).

The species was collected for the first time along the Gulf of Naples at Posillipo in 1882 (Sector C) by an unknown collector; it was identified by Raffaello Valiante, that one year later published his monograph on the varieties of *Cystoseira* in the Neapolitan Gulf (‘Le Cystoseirae del Golfo di Napoli’), with 15 extraordinary lithographic tables. In the Michigan Herbarium (USA) there are dried specimens collected by Martens and Reed (at the beginning of 1900), collected at ‘Naples’. During the 20th century, the species was collected in 1903 by Angelo Mazza close to the Castle of Baia, at Portici and at San Giovanni a Teduccio (Sectors B, C). Georg Funk (1927,1955) in his publications and diary he gave detailed information on the presence of CA providing map of presence in Ischia (A), Isolotto di San Martino, Capo Miseno (B), Punta Pennata, Nisida, Posillipo, Gaiola (C), affirming that it was ‘very common’ in Grotta del Tuono (‘Thunder cave’) corresponding with the currently toponymy of “Grotte di Trentaremi”. After Funk, we have also many voucher herbaria testifying the presence in the gulf but the name of the collector is not reported.

Ernst (1959) and later Feoli & Bressan (1972) studied the benthic vegetation along the Sorrento Peninsula (Sector D) providing further information on the distribution of this genus in the southern part of the gulf. The occurrence of *Cystoseira* spp. in this area over 1980 is documented by the pictures made by local professional photographers, Enrico and Maria Rosaria Gargiulo gathered through the citizen science project. They recorded the species at Punta del Capo, Serra Capriola, Puolo west Bay, Capo Corbo, S. Liberatore, Punta S. Lorenzo, and Le Fontane (Sector D).

As regard the Ischia Island (Sector A), until the end of 1980, CA occurred on the rocks in front of Villa Dohrn (Buia, pers. comm.).

The re-surveys of HS testify that on the opposite side of the gulf, that is S. Martino Island (Sector B), where the natural rocky coastal line has been replaced by artificial substrates, this species is now absent and in addition a dense *Mytilus galloprovincialis* community has been established.

In the Sector C (the Naples Bay), CA is completely absent from Mergellina (Posillipo) to the eastward end of the sector for a coast length of about 42 km (scale 1:250,000); this species occurs again (following southward the coastline development) only in Sorrento peninsula (Sector D). Historical populations were naturally isolated by sandy beaches (as the mouth of Sarno river between Torre Annunziata and Castellammare di Stabia); CA was present at San Giovanni a Teduccio, Torre del Greco, Torre Annunziata (Sector C) as reported by HRs of Mazza, in 1903 (probably on rocky platforms off these site).

In this area currently a dense stand of mussels, in an articulated corallines and *Enteromorpha* spp. community currently thrive: no *Cystoseira* spp. has been recorded.

The species disappeared also at Nisida and Porto Paone (Sector C, only one specimens has been observed in Porto Paone in 2014, no further observation afterwards). It is important to note that in the Sector D the species was abundant (Gargiulo & Gargiulo, pers. comm.) and now it has completely collapsed between Sorrento and Punta del Capo (2 km).

Around the Island of Capri (Sector E) this species was primarily recorded only in 2001 by Ribera d'Alcalà & Russo, in the frame of a Feasibility Report for the establishment of a Marine Protected Area.

Considering historical sites, a 60% of regression was recorded (LI).

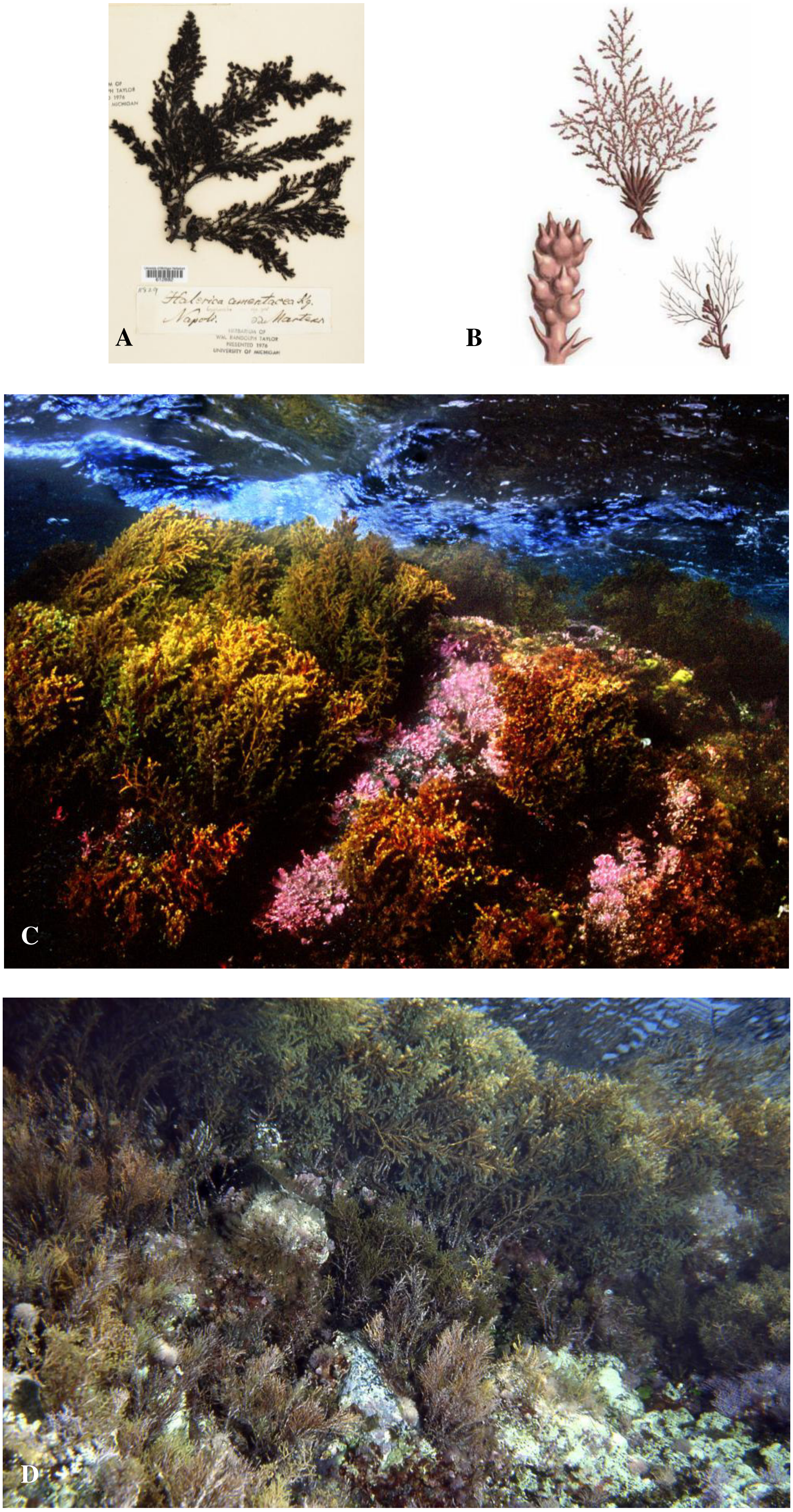


Figure 62: *C. amentacea.* A: Voucher from Michigan herbarium. B: drawings from Valiante (1883). C and D: in situ pictures by E. Gargiulo (C, D, about 1985)

Cystoseira barbata (Stackhouse) C.Agardh

In the Mediterranean Sea, *Cystoseira barbata* (CBA, Figure 63) thrives in the upper sub-littoral zone, in sheltered and shallow sites but also in coastal lagoons with low hydrodynamic conditions. In the study area, this species is sometimes cited as *Cystoseira hoppei* C.Agardh 1820 and erroneously as *C. Hoppii* in some herbarium vouchers.

The first records was dated 1864, collected by C. Bolle and preserved at the Herbarium of Università di Padova. Subsequent specimens come from Falkenberg (1879), Herbarium of Roma-La Sapienza (1881, 1882). In the 19th and 20th centuries, CBA was collected 32 times in the gulf: vouchers from Michigan University Herbarium by Bradley Moore Davis (1904), Funk (1927), Herbarium of SZN (without collectors), and Ernst (1959).

This species was widely distributed: Ischia, Ischia Harbour (sector A); Bacoli, Capo Miseno Castello di Baia (Sector B); Capo Coroglio, Posillipo, Nisida north side, Badessa bank (the past misunderstood Gaiola bank), Capo Posillipo, Villa Maista, Porto Rendell (Posillipo), Posillipo-Punta Cinita, Nisida Island, Porto Paone, Trentaremi, Donnanna-Grotta Romana, Napoli, Marechiaro, Napoli-Via Caracciolo (Sector C); Sorrento Peninsula (Sector D).

The last record of this species is dated 1968 (SZN Herbarium).

No specimens were found during HS re-survey; Loss Index = 100 %.

Figure 63: *C. barbata* vouchers herbaria. A: Herbarium SZN, B: Michigan Herbarium; C: Herbarium SZN; D: Valiante (1883)

Cystoseira barbatula Kützing

Cystoseira barbatula (CBB, Figure 64) is typical of clean, moderately rough waters (Cormaci et al. 1992). It grows in upper sublittoral zone, 1-1.5 m depth, on open and exposed rocky shores (Berov et al., 2015).

This specie was described in 'Naples' by Kützing in 1860. Concerning the recent record of *C. barbatula* in the gulf reported by Buia et al. (2013a), I personally reviewed frozen samples and I can exclude its current occurrence.

The history of this species is very complex: it has been described for the first time by Kützing on a specimen collected by Sonder in 'Naples' but paintings and descriptions are not exhaustive (Cormaci et al. 1992). After that, there are no other records for the gulf. It is possible that this species was present in the past in the study area, but there is uncertainty on that. It is currently present in Sicily (Cormaci et al. 1992) and as the case of *C. tamariscifolia* (see next) could be historically disappeared in the gulf.

The LI index is equal to 100%.

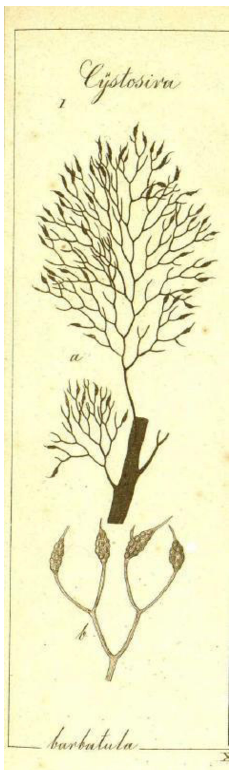


Figure 64: *C. barbatula* (Kützing, 1860)

Cystoseira brachycarpa J.Agardh

*Cystoseira brachycarpa (*CBR, Figure 65) grows in littoral rock-pools and sublittoral habitats, in moderately exposed sites and with high light intensity. Some historical records were cited under the names of *Cystoseira balearica* Sauvageau, *Cystoseira brachycarpa* var. *balearica* (Sauvageau) Giaccone and as *C. brachycarpa* J. Ag. (= *C. crinita* Valiante) by Funk (1927, 1955). For that reason, historical records reported for this species in the study area were probably confused with *Cystoseira crinita* Duby reported by Valiante (1883) and considered by Funk as above mentioned. In this thesis, all the records of Funk (1927) and previous ones dealing about *C. crinita* have been updated.

Despite the number of records (18), *Cystoseira brachycarpa* seemed to be widespread in the gulf. It was common along the north and north-east coasts of the Ischia Island (Funk, 1927) (Sector A); at Baia, Bagnoli, Isolotto di San Martino (Sector B); Nisida Island, Torre del Greco, Posillipo, Badessa Bank (Sector C). It was collected for the last time in Naples by Giaccone in 1971 (Catra & Grimaldi, 2003) and the last HR is referred to Feoli and Bressan (1972) (Sector D).

During the 2013-2016 re-survey, the species has been observed only in the historical point of Marina Piccola (Capri Island) (Sector E).

A general regression is evident with a LI= 94%

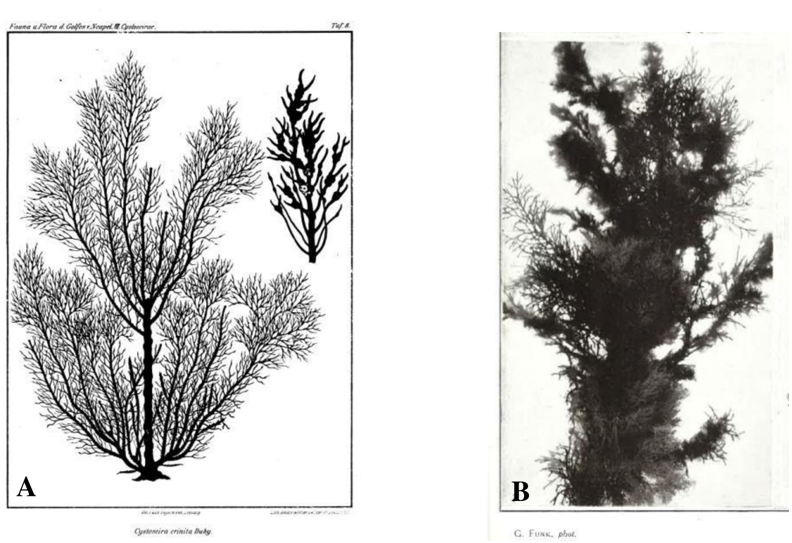


Figure 65: *C. brachycarpa* (A: Valiante, 1883; B: Funk, 1927)

Cystoseira compressa (Esper) Gerloff & Nizamuddin subsp. *compressa*

Cystoseira compressa subsp. *compressa* (hereafter CCc, , Figure 66) grows in the upper sublittoral zone from sea surface to 15 m, at both sheltered and exposed sites, in pristine and moderately polluted areas, generally forming large populations at low water mark; some individuals have occasionally been observed at 40 m depth (Thibaut et al. 2015a). This species co-occurs with articulated corallines and *Mytilus galloprovincialis* (sometimes also on artificial barriers) but is absent around the entrance of harbours. It is common that *C. compressa* dominates over *C. amentacea*, also when this last species is abundant.

Historical records cited this species as *Cystoseria abrotanifolia* (Linnaeus) C. Agardh; *Cystoseira abrotanifolia* f. *fimbriata* Sauvageau, *Cystoseira fimbriata* Bory.

Cystoseira compressa was first collected in 1838 at Naples, by Joseph-Louis Bonjean (Botaniste a Chambery). The specimen is preserved at the Herbarium Pirotta, (Università di Roma - La Sapienza). This was the most common *Cystoseira* species recorded in the study area (Annex I) with 52 historical sites (HS) of occurrence. In the 19th century CC was collected in Lacco Ameno (Ischia, sector A), Naples, Posillipo, Portici, Torre del Greco (sector C); later, in the 20th century, it was observed in several other sites in all the sectors: Ischia Harbour (sector A), Isolotto di S. Martino, Acquamorta (Maremorto), Bacoli, Banco di Biondo Palomba, Castello di Baia, Capo Miseno (sector B); Nisida, Punta Pennata, Capo Posillipo, Castel dell'Ovo, Mergellina (Sector C), Sorrento peninsula (sector D), Capri (Sector E).

In the Michigan Herbarium (MICH-USA) there are specimens collected by Moore at the beginning of 1900 in 'Naples'.

During the HS re-survey, this species disappeared in those sites close to harbours (Acquamorta, Sector B; Nisida, Castel dell'Ovo, Mergellina, Via Caracciolo, Portici, Torre del Greco, Castellammare, Sector C; Sorrento, Sector D) and where new infrastructures (artificial barriers) have been deployed or where land reclamation took place (Ischia north side, Vivara, Sector A; Acquamorta, Sector B; Santa Fortunata Camping, Punta del Capo, Sector D;, Punta Carena, Capri, Sector E) .

C. compressa was absent in the inner part of the gulf (34 km), westward from Capo Posillipo (Sector C) to rocks close to Bikini Beach eastward, Sorrento Peninsula (Sector D). LI computed for this species is equal to 69%.

Figure 66: Herbarium voucher of *C. compressa*, collected at Casamicciola (1962, A). Michigan Herbarium (about 1900, B). Photos of E. Gargiulo (about 1985; C, D)

Cystoseira compressa subsp. *pustulata* (Ercegovic) Verlaque

Cystoseira compressa subsp. *pustulata* (CCp, Figure 67) grows in shallow sublittoral zones (Thibaut et al., 2015a) and rock-pools.

In the study sites there were no old references related to this subspecies. In the SZN Herbarium that I revised for the thesis, I found one specimen (anonymous collector), collected in Ischia between Ischia Harbour and Lacco Ameno in 1962, that I identified as *Cystoseira compressa* subsp. *pustulata*.

In the period 2013-2016 no specimen were found in the historical site.

LI=100%

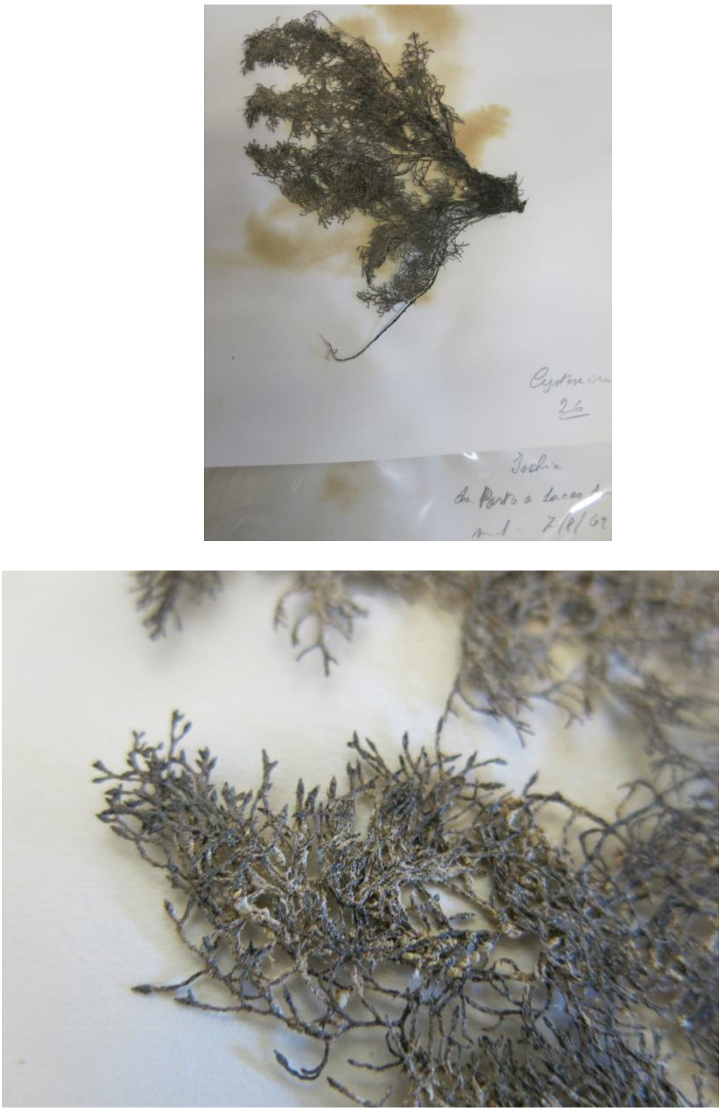


Figure 67: *Cystoseira* sp. collected between the Ischia Harbour and Lacco Ameno that I identified as *C. compressa* subsp. *pustulata* (Herbarium SZN)

Cystoseira crinita **Duby**

Cystoseira crinita Duby (CRI, Figure 68) grows in upper sublittoral zone, near the sea surface, in shelter locations with high light intensity and warm temperatures in summer (Thibaut et al., 2015a).

HRs for this species are very few. It is not clear if it is related to the incorrect interpretation of the historical issue related to *Cystoseira brachycarpa* (due to my revision) and the misleading reference of Valiante (1883) about this species.

The few records of *C. crinita* in the entire study area, are those by Feoli and Bressan (1972) in Cala di Mitigliano (Sorrento Peninsula, Sector D) and by Cinelli (1976b) for Vivara Island (Phlegrean Islands, Sector A), the latter considering this species as one of the most abundant along the island between 7-10 m. In the herbaria that I revised, there are also two specimens (anonymous collector), collected between Ischia Harbour and Lacco Ameno in 1962, that I identified as *Cystoseira crinita* and *Cystoseira* cfr. *crinita*.

The Index of Loss computed for this species is 100%.

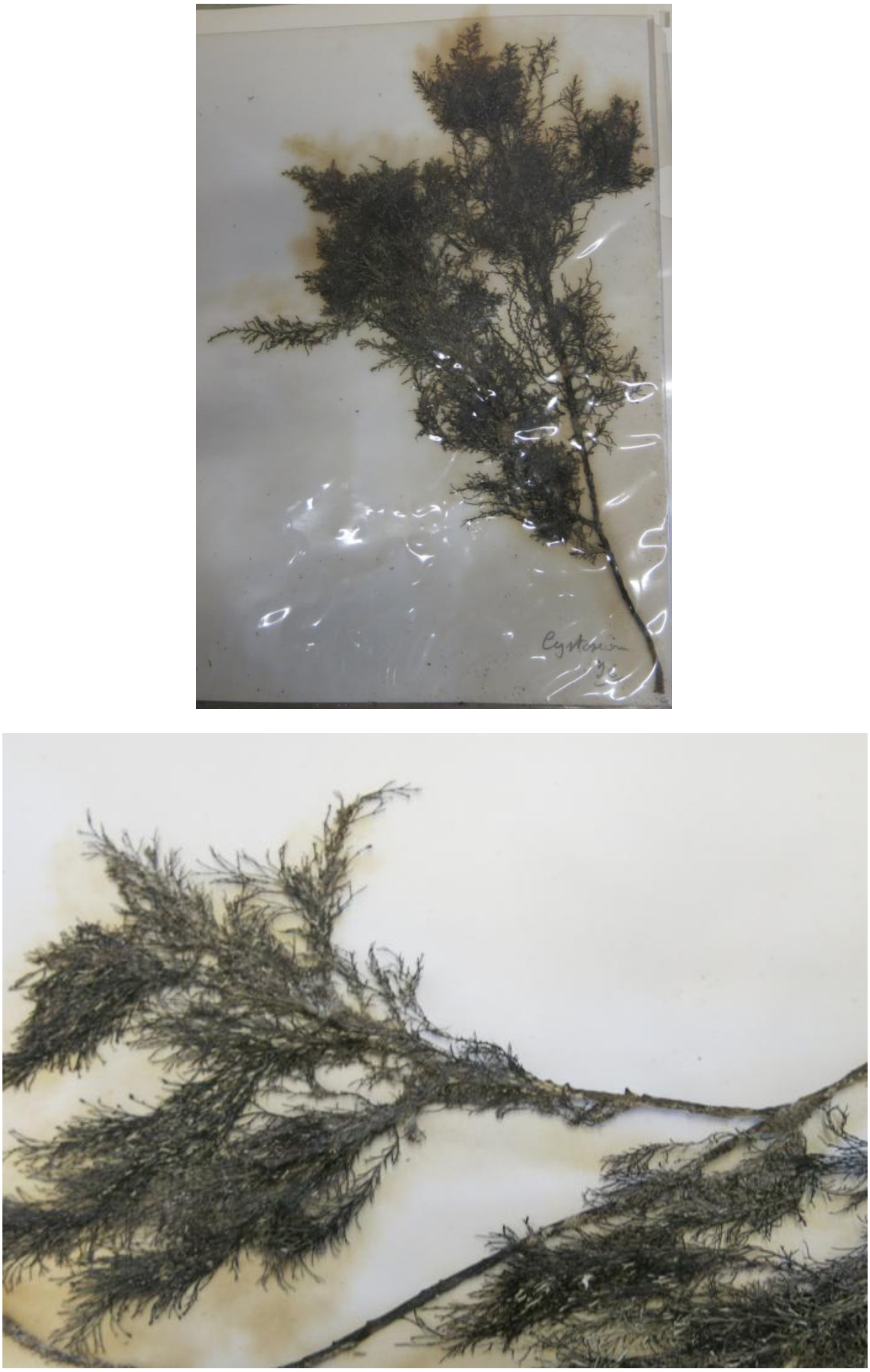


Figure 68: *Cystoseira* sp. collected between the Ischia Harbour and Lacco Ameno that I identified as *Cystoseira crinita* and *Cystoseira* cfr. *crinita* (Herbarium SZN)

Cystoseira dubia **Valiante**

Cystoseira dubia (CD, Figure 69) grows in lower littoral and upper circa-littoral zone with low hydrodynamic conditions, intense sedimentation with a low light intensity (1-0.3 % of surface irradiance) and a temperature of 14-16°C (Tina et al., 1994, Mannino & Mancuso, 2009).

The species was collected in the Gulf of Naples by Berthold (1882, SZN Herbarium) for the first time in 1880; it was described by Valiante (1883) as a new species collected at the Secca di Biondo Palomba (commonly incorrectly known today as Secca di Benta Palumbo) at depth between 40 and 60 m. Also Funk (1927) collected this species in the same bank and in Torre Annunziata, Punta Carena (Capri, E) and Punta S. Pancrazio (Ischia, A). A complete well preserved specimen is present at the SZN Herbarium, dated 24 September 1913 (legit Funk).

Figure 69: The *C. dubia* specimen preserved at the SZN Herbarium

In general, literature data are scant about this species: some information is available from Tina et al. (1994), and from Mannino & Mancuso (2009) from Sicilian waters. This species has been collected by this authors at a shallower bathymetric range than that reported for the HR in the Gulf of Naples. In the study area indeed, CD has been collected between 40 and 100 m (Funk, 1927). After Funk (1927), Cinelli (1971) collected the species at Punta S. Pancrazio (Ischia, sector A) where he found only two individuals at 40 m.

During my re-surveys in 2013-2016 in very deep historical sites of Punta S. Pancrazio, Punta S. Angelo, Torre Annunziata, Punta Carena, I reached the maximum depth of 50 m without recording the species. R.O.V. video analysis was used for deeper stations but no specimens were recorded (Bavestrello et al., 2014; Angiolillo et al., 2015).
The Loss Index for this species is 100%.

Cystoseira foeniculacea (Linnaeus) Greville

Cystoseira foeniculacea (CF, Figure 70) grows in sheltered places, in rock-pools and along the littoral zone from 0 to 20 m. Historical records cited this species as *Cystoseira discors* (Linnaeus) C.Agardh.

CF was collected in all the sectors of the gulf. It was reported by Gamulin-Brida et al. (1967) at Punta Solchiaro; it was considered common in Baia, Arco Felice (the current name of the area is Lucrino beach), Miseno (Sector B), Nisida, Badessa Bank (the misunderstood Gaiola Bank) Posillipo (Palazzo Manzi, Cala Garofano, Palazzo Donn'Anna, Grotta Romana, Palazzo Volpicelli), Torre del Greco (Sector C). In the Herbarium of University of California, (Berkeley, USA) there is a specimen collected at 'Naples' by Minnie Reed, in 1911 (Catalog #: UC170558). There was only one record at the Vervece bank (Funk, 1927), while various specimens were collected along the Sorrento Peninsula (Ernst, 1959) (Sector D) and a voucher from SZN Herbarium was collected at Capri (Sector E), by an anonymous collector (1957). Currently, the species has been found only at Capri (Sector E).

For this species LI is 96%.

Figure 70: *C. foeniculacea* (A: Ernst, 1959; B: Herbarium SZN, C: Herbarium of University of California (USA)

Cystoseira funkii Schiffner ex Gerloff & Nizamuddin

Cystoseira funkii (CFu) grows in deep zones between 25 and 50 m characterized by strong currents. It was described for the first time at the Vervece Bank (Sector D) by Gerloff & Nizamuddin (1976) (Figure 71). This taxon shares some similar characters with *Cystoseira spinosa* but the taxon is currently accepted (Guiry & Guiry, 2016).

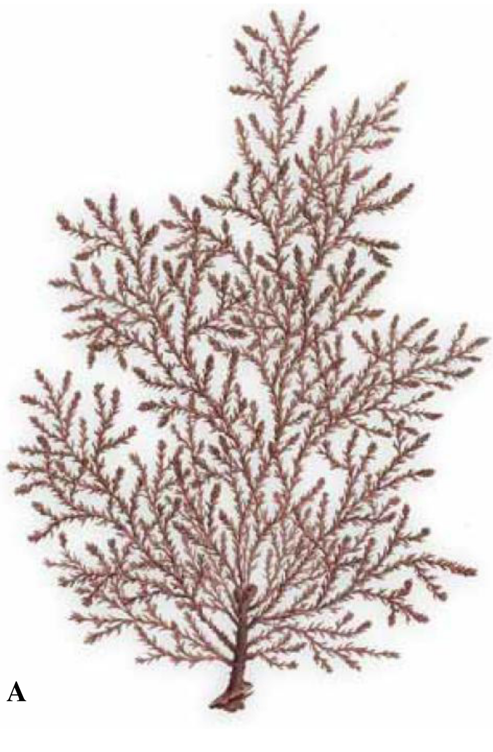
I did not find this species during 2013-2016 re-surveys and therefore the computed LI is 100%.

Figure 71: *C. funkii* fragment of the holotype (Gerloff & Nizamuddin, 1976)

Cystoseira mediterranea Sauvageau

Cystoseira mediterranea (CMe, Figure 72) is widespread in the Mediterranean Sea with the same ecology of *C. amentacea*. It is reported as abundant in the Gulf of Leon (between North of Cataluña and south of France), but it is also cited in many localities of the Western Mediterranean (Rodríguez-Prieto et al. 2013).

HRs report this species in Ischia, Procida (A), San Martino (B), Miseno Cape (B), Posillipo (C), Capo di Sorrento (D). The first record is by Funk (1927) in Grotte di Trentaremi (Grotta del Tuono, Thunder Grotto) close to Gaiola Island. It is possible that the specie has been sometimes misidentified in the past with *C. amentacea* and doubtful identifications possibly occurred due to the Valiante's (1883) pictures and of Funk (1927, 1955) records. Assessments on these misidentifications are complex due to the lack of referenced dry samples or to incomplete specimens kept in herbaria. In any case both species are considered of high level of sensitiveness by Ballesteros et al. (2007). The species was currently found in the HS of S. Anna, Posillipo (Marechiaro and Palazzo Manzi). The computed Loss Index for this species is 76%.


A

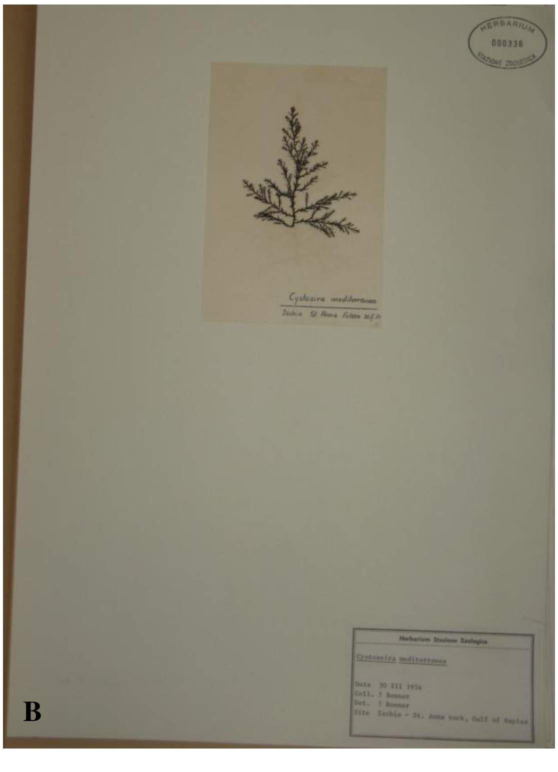

B

Figure 72: *C. mediterranea* (A: Valiante 1883, reported here as *C. amentacea*; B: Herbarium SZN)

Cystoseira sauvageauana Hamel

Cystoseira sauvageauana (CSA, Figure 73) generally grows in sheltered places in the littoral and sublittoral zones, down to several meters depth (Thibaut et al., 2015a). Historical records were cited as *Cystoseira selaginoides* Sauvageau. The first specimens were collected in 1882 at Posillipo, between 2 and 30 m by Valiante; the samples are preserved in the Herbarium of Università di Roma-La Sapienza.

In the Valiante's monograph 'Le Cystoseirae del Golfo di Napoli', this species is reported to be present at Capo Miseno, Punta Pennata (B), Nisida and Secca della Badessa (C) (Funk 1927)

In the SZN Herbarium there is a specimen from Capri, collected by anonymous on 28th of July 1957, and identified as *C. opuntioides* Bory, currently *Cystoseira zosteroides* (Turner) C.Agardh. I re-identified the specimen as *C.* cfr. *sauvageauana*.

Only 8 records of this species were cited in the gulf, we re-surveyed all the HS and the species was observed only at 1 site (Capri).

The LI was 83%.

Figure 73: *Cystoseira sauvageauana* (A: Valiante 1883; B: the specimen of SZN herbarium named *C. opuntioides* and re-identified as *C.* cfr. *sauvageauana*)

Cystoseira sedoides **(Desfontaines) C.Agardh**

Cystoseira sedoides (CSE, Figure 74) thrives in shallow habitats (0.3-1.5 m) with medium level of hydrodinamism. This species currently has as very restricted distribution area (Tunisia; Algeria; Pantelleria Island, Italy) (Rodríguez-Prieto et al. 2013, Guiry & Guiry, 2016). Despite that data, Delle Chiaje (1829) reported this species in the Pozzuoli Gulf. This is the unique report of this specie in the study area, and the picture reported by Delle Chiaie is not very clear, displaying doubtful characters.

The survey didn't allow to find this species and the LI was 100 %.

Figure 74: *Cystoseira sedoides* (Delle Chiaje, 1829)

Cystoseira spinosa Sauvageau var. *spinosa*

Following the HRs, CS was present in the study area with three varieties: *Cystoseira spinosa* Sauvageau var. *spinosa* (Figure 75), *Cystoseira spinosa* Sauvageau var. *compressa* Cormaci, Furnari, Giaccone, Scammacca & Serio (Figure 76) and *Cystoseira spinosa* var. *tenuior* (Ercegovic) M.Cormaci, G.Furnari, G.Giaccone, B.Scammacca, & D.Serio (Figure 77).

Some historical records were cited respectively under the names: *Cystoseira erica-marina* (S.G.Gmelin) Naccari; *Cystoseira adriatica* Ercegovic *f. compressa* or *Cystoseira montagnei* J.Agardh and *Cystoseira adriatica* f. *tenuior* (Ercegovic) Giaccone 1973.

Cystoseira spinosa Sauvageau var. *spinosa* (CSs) thrives from the infra-littoral to the circa-littoral zone. After my revision of samples and herbaria of specimens collected in the Gulf of Naples, *C. erica-marina* can be considered as synonymous of *C. spinosa* var. *spinosa*.

Cystoseira spinosa Sauvageau var. *spinosa* (Figure 75) was collected for the first time by Valiante in Posillipo (B) (Herbarium Università di Roma-La Sapienza, 1882), then at Nisida, Secca della Badessa, Santa Lucia (Valiante, 1883) (C). In the 20th century this variety was collected in Forio Bank (A), Bacoli, Capo Miseno (B), Posillipo (C), Marina Piccola (E) by Funk (1927); later Cinelli (1971) recorded the variety at Capo Miseno, Ischia east side (1957, Herbarium SZN other collections), Punta S. Pancrazio (Ischia). The Funk Diary listed the taxon present also in Banco d'Ischia (A), Bacoli, Castello di Baia (B), Capo Posillipo, and close to Grotta Azzurra (Capri). Cinelli (1971) referring to deep algae of S. Pancrazio found the two varieties (CSs, CSc) both mixed with *C. zosteroides* and forming monospecific assemblages in that area.

During our surveys this taxon has been recorded at San Pancrazio but very spotted and non-forming monospecific assemblages, as reported in the past by Cinelli (1971).

The Loss Index (LI) computed for CSs is 94 %.

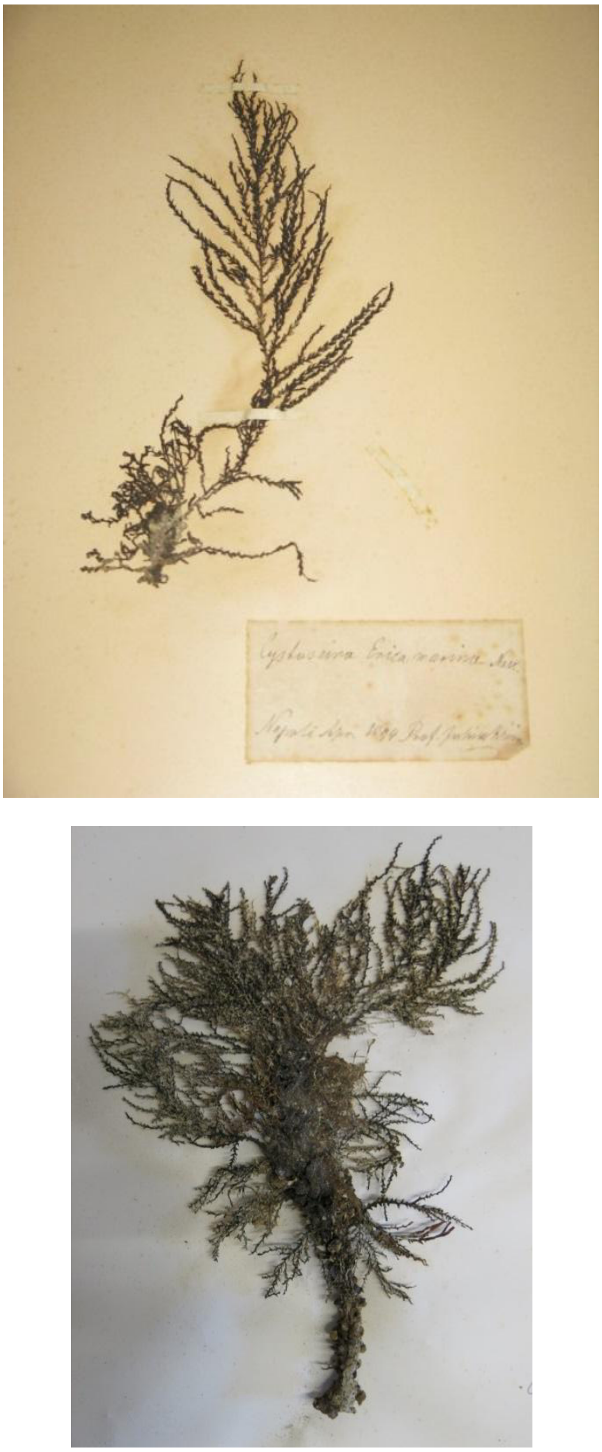


Figure 75: *C. spinosa* var. *spinosa* from voucher herbaria (Herbarium SZN)

Cystoseira spinosa Sauvageau var. *compressa* Cormaci, Furnari, Giaccone, Scammacca & Serio

This variety (CSc, Figure 76) is typical of deep habitats from 20m depth down to ~70 m. It was first reported in the studied area by Valiante (1883) in Secca di Biondo Palomba (the misunderstood Secca di Benta Palumbo, Sector B), Secca della Badessa (the misunderstood Secca della Gaiola, Sector C), Punta Campanella (D). In the 20th century Funk (1927) reported this taxon in Forio Bank (A), Secca di Biondo Palomba, Capo Miseno, Punta Pennata (B), Secca della Badessa, Posillipo - Palazzo Manzi, San Giovanni a Teduccio Bank, Secca del Campanile (C), Scoglio Vervece Bank (all around the big rock) (D), Bocca Piccola Bank, and close to Grotta Azzura (Capri, E). I found also voucher specimens from Capri (1957) and further records came from Ernst (1959) in Sorrento peninsula (Ciercio Bay, Punta di Massa, between Punta di Sorrento and Sorrento, D). At SZN Villa Dohrn, I found a specimens of CSc in formaldehyde dating back to 1960, from Banco di Forio (Ischia, A). The last record of this taxon is from Cinelli (1971) from Punta S. Pancrazio (Ischia, A). He recorded mixed populations with *C. zosteroides* and monospecific assemblages.

On the basis of my revision of samples and herbarium specimens, past samples labelled as *C. montagnei* were based on Valiantes' descriptions (Valiante, 1883); however, they have been identified as *C. spinosa* var. *compressa*.

During the HS surveys the taxon was only observed in 4 sites (San Pancrazio, Punta Campanella, Vervece bank and Capri) with very spotted individuals.

The Loss Index computed for CSc is 82 %.

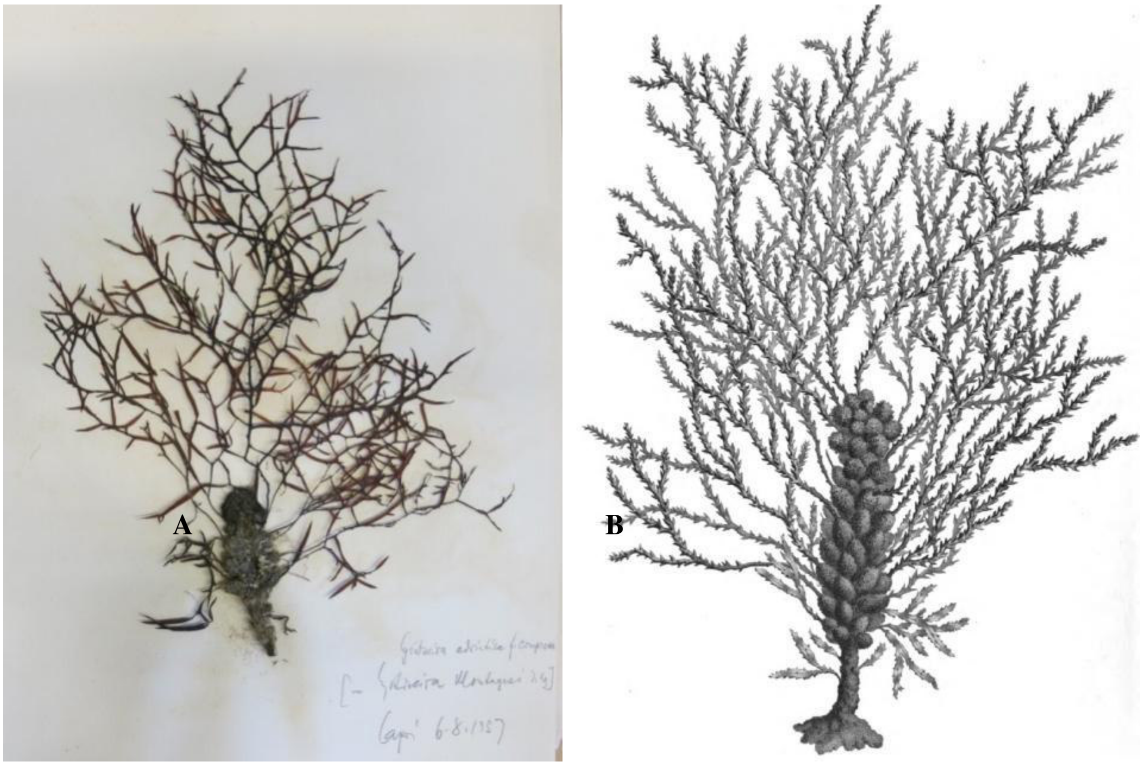


Figure 76: *C. spinosa* var. *compressa* from Funk Herbarium preserved at SZN (A) and Valiante (1883) (B)

Cystoseira spinosa var. *tenuior* (Ercegovic) M.Cormaci, G.Furnari, G.Giaccone, B.Scammacca, & D.Serio

Cystoseira spinosa var. *tenuior* (Ercegovic) M.Cormaci, G.Furnari, G.Giaccone, B.Scammacca, & D.Serio (CSt, Figure 77) is typical of shallow habitats between 0 and 2-3 m depth, in sheltered zones.

This taxon has been collected in 1957 at Capo Miseno as *C. adriatica* f. *tenuior* (Herbarium SZN – other collections). We did not find this variety during our HS re-surveys at Capo Miseno.

Figure 77: *Cystoseira spinosa* var. *tenuior* (SZN Herbarium)

The Loss Index (LI) computed for CSt is 100 %.

Considering all the varieties of *C. spinosa* (CSs, Csc, CSt), we have 34 HS in the study area.

For all these three varieties we formulated a unique Loss Index that was 90%.

Cystoseira tamariscifolia (Hudson) Papenfuss

Cystoseira tamariscifolia (CT, Figure 78) is exclusive of infralittoral fringe between 0 and 3 m. Some historical records were cited under the name of *Cystoseira ericoides* (Linnaeus) C.Agardh.

Delle Chiaie (1882), Falkenberg (1879) and other past authors on the basis of different exiccata from herbaria indicated the presence of *Cystoseira tamariscifolia* in the Gulf of Naples. After 1898 (Herbarium Torino) no *C. tamariscifolia* record has been reported. Only species bearing some similar taxonomical characters have been reported in the gulf as *C. amentacea* and *C. mediterranea*. These three species in literature are considered related species (they are paired together in the Groupe III or clade 5 or 'Groupe mediterranea' respectively by Guern, 1962; Draisma et al. 2010; Robvieux, 2013).

Some authors think that this species can occur only in areas under Atlantic influence (Southern Spain, Sicily, Malta and Algeria) (Ribera et al. 1992, Gomez-Garreta et al. 2001). *C. tamariscifolia* is currently present in Sicily (Furnari et al. 2003). In the Gulf of Naples, it was first reported by Delle Chiaie (1882), then by Falkenberg (1879) while some exiccata derive from the Herbaria of the University of Padova (1864), Torino (1898) and Roma (Pirotta).

Later, no *C. tamariscifolia* records have been reported anymore.

The computed LI is 100%.

Figure 78*: C. tamariscifolia* (Delle Chiaje, 1829)

Cystoseira zosteroides (Turner) C.Agardh

Cystoseira zosteroides (CZ, Figure 79) grows in the sublittoral zone generally from 15 down to 80-100 m. Some historical records cite this species as *Cystoseira opuntioides* Bory ex Montagne 1846. The species was first reported by Falkenberg (1879) in various sites (Biondo Palomba Bank, Massa Lubrense, Capri). Valiante (1883) reported this species in the Sector C (S. Lucia, Napoli, close to Castel dell'Ovo at a depth 4-7 m.

In 20th century, the species was present in Portici (Mazza, 1903). Funk (1927) on his publication and Diary described this species in Secca di Biondo Palomba (Sector B), San Giovanni a Teduccio, Secca della Badessa (Sector C) and Capri (Sector E). I examined a voucher specimen of *C. zosteroides* fixed in formaldehyde dating back to 1960, from Secca di Forio.

The last record of this species from the gulf is from Cinelli (1971) from Punta S. Pancrazio (Ischia) were it was widespread.

During the HS survey, I found the species only in San Pancrazio, from 30 to 34 m with a good number of isolated individuals but not forming a dense and monospecific assemblages. The LI is 89%.

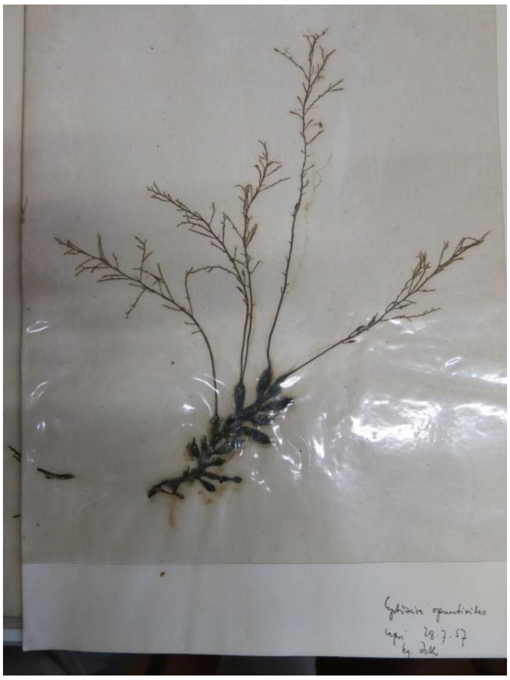


Figure 79: *C. zosteroides* (Capri; Herbarium SZN, 1957)

Sargassum acinarium (Linnaeus) Setchell

Sargassum acinarium (SA, Figure 80) usually grows in the sublittoral zone from 20 m of depth (Rodríguez-Prieto et al. 2013). In literature, some historical records were cited under the names: *S. linifolium* C. Agardh.

The first record of the species, dated back to 1829, was described in Baia by Delle Chiaje. Then the species was found in Posillipo and was considered ‘widespread’ in Baia (Falkenberg, 1879). In 1898, Micheletti (PAD) collected this species on the seabed of Saccomanno beach (‘Sul letto del mare alla spiaggia di Saccomanno, Isola d’Ischia’). In the same herbarium there is a voucher of the same year of another specimen collected from Portici (Sector C). Also Mazza (1903) collected the species in the same place 5 years later. Funk (1927) collected the species in: Ischia Harbour (A), Punta Terone (B), Castel Dell’Ovo, Grotta del Tuono, Porto Rendell, Capo Posillipo (C). The species was collected by Bonner in Rocce di S. Pietro, Ischia (Herbarium SZN, 1954). In the same Herbarium there are specimens collected in 1957-61 from Capo Posillipo, Santa Lucia (C), Capo di Sorrento (D), Capri (E). In the TO Herbarium there are specimens collected by Malinverni and Gennari and the species was then collected in Procida (Punta Solchiaro, Sector A) by Gamulin-Brida et al. (1967). There is also a specimen preserved in the herbarium from Palazzo Donnanna-Grottaromana (Posillipo, Sector C), that dates back to 1968: this is the last record of this species.

The LI was 100%

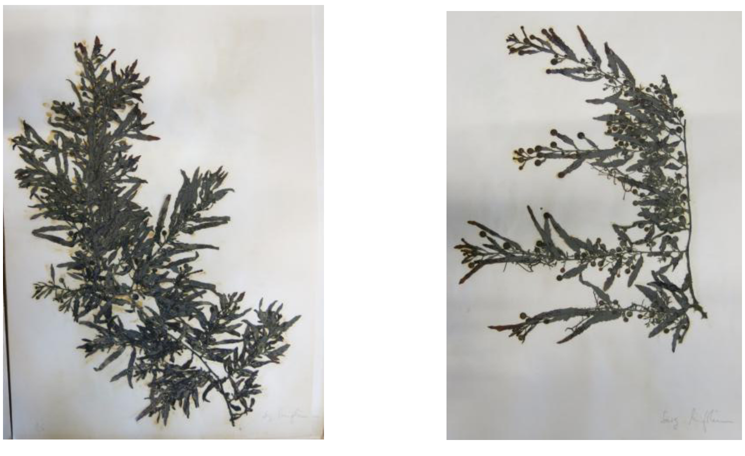


Figure 80: *Sargassum acinarium* (Herbarium SZN)

Sargassum hornschuchii C.Agardh

Sargassum hornschuchii (SH, Figure 81) usually grows in the sublittoral zone, also very deep. Some historical records were cited under the names of *Sargassum anceps* Delle Chiaje.

The first specimen was collected close to the Harbour of Ercolano (Delle Chiaje, 1829), a drift specimen in October (‘*Inter marinas quisquilias prope Porticus Herculanenses octobris mense vidi*’). It is considered by Falkenberg (1879) rare if compared to *S. acinarium* and found it only in 50-80 m. He wrote he found this species in summer in Capri. In the 20^{th} century the species was collected in Torre del Greco (Mazza, 1903), Procida, Miseno (Herbarium SZN, 1911), Secca di Biondo Palomba (Funk, 1912; Herbarium SZN). The species was then collected in Procida (sector A), Secca di Bocca Piccola (the current deep bank “La Secchetella”) and Vervece bank (Est, Nord, S-W) (Sector D), Capri (close to Blue Grotto, Punta Carena, Capri North side) by Funk (1927). In the SZN herbarium we have specimens from Capo di Sorrento (1957), Capri (1957), Capo Posillipo (1963). The species was collected by Cinelli in Punta San Pancrazio at 30 m (Ischia Sector A) and in Cala di Mitigliano (Sorrento peninsula, Sector D) by Feoli & Bressan (1972). The last record is from Zupo & Buia (2000) in Banco di S. Croce (Vico Equense, D).

I never found this species during my surveys and the calculated LI was 100%.

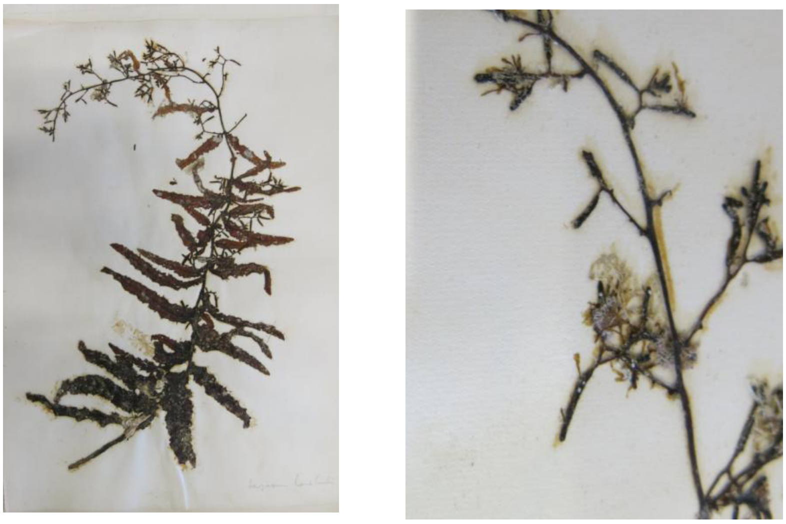


Figure 81: *Sargassum hornschuchii* (Herbarium SZN)

Sargassum vulgare C.Agardh

Sargassum vulgare (SV, Figure 82) grows in rock-pools, on moderately wave exposed (i.e. bays), sheltered rocks and in the sublittoral zone, down to approx. 40 m depth.

This species was reported by Delle Chiaje (1829) in Gaiola on rocky habitats (‘Adhaeret saxis Euplaeae’). It is the unique published record for the 19th century, and then there was a gap of 154 years: the species was collected in 1983 by Buia and preserved in the SZN Herbarium (Ischia, Punta Caruso, 18 m).

Then the species has been reported few years ago around Castello Aragonese and Punta San Pancrazio (Porzio et al. 2011, Chiarore et al. 2012) in the framework of recent studies related to ocean acidification.

Few information gathered from the Citizen project developed in this thesis, added more recent records. Photos and personal communications, from the popular underwater photographers Gargiulo Enrico and Maria Rosaria testified the presence of this species all along the coast between Sorrento and Punta del Capo (in dense stands of 1 m long between Bagno delle Sirene and Ninfeo Antico, in 1985); in addition, their son Marco Gargiulo photographed the species in Banco di Santa Croce (Vico Equense) at about 20 m depth in the 90s.

I revisited the HS and I found the species at Castello Aragonese and Punta S. Pancrazio (Sector A), at Gaiola at a distance of 500 m from the island to another area called Tavola di Mare (Baia Trentaremi zone) (Sector C). The species has disappeared between Sorrento and Capo di Sorrento (Sector D).

The LI index for this species is 75%.

Figure 82: *Sargassum vulgare*. A: Herbarium SZN. B and C: Photos of E. Gargiulo (about 1985)

Cystoseira sp.

HRs of Fucales only reporting '*Cystoseira* sp.' only were frequently found during my bibliographic research. Apart from Funk (1927) and Gamulin-Brida (1965), these records mainly derive from floristic list of species generated for ecological studies, lacking of expert identification. The records are dated to the end of the 20th century and beginning of 21st century and are referred to Sorrento peninsula (south side of Baia di Puolo, Cala di Mitigliano, Le Fontane-Punta Sorrentina, Marina Grande di Sorrento south side, Punta Gradelle, between Punta Corbo and Punta Sorrentina, Punta del Capo, Punta S. Lorenzo, S. Liberatore - Punta Sorrentina) (Sector D) by Gargiulo (1985, pers. comm.), Formiche bank, Gaiola-Tavola di Mare (Simeone pers. comm.), Capri (Punta del Fucile, Punta Trasete, Scoglio del Monacone, Punta del Capo-Scoglio della Ricotta) (Sector E) (Ribera d'Alcalà & Russo, 2001), Posillipo-Tavola di Mare (Simeone pers. comm.), Gaiola-Marechiaro, Rocce Verdi, Trentaremi, Coroglio Casamicciola (in front of Pio Monte della Misericordia) (ARPAC, 2007).

We didn't find any *Cystoseira* sp. in many of the HRs re-surveys, computing a Loss Index (LI) of 58 %. In the Annex I, are available the current identifications of the species encountered in the HS where *Cystoseira* sp. records have been confirmed.

Sargassum sp.

HR of Fucales reporting '*Sargassum* sp.' only was often found during my bibliographic research. It was present in 1927 in Nisida north side (Funk,1927), Posillipo, Punta Cinita, (Funk's Diary), Banco di Miseno (Parenzan, 1956), Sorrento coast (Ernst, 1959), Capo Posillipo (1961), Miseno (1962), Capo Posillipo (1963), Gaiola and Santa Lucia (1963) (Herbarium SZN), Nisida-Porto Paone (Gamulin-Brinda, 1965), Trentaremi (1965), Marina Grande di Sorrento, Punta Gradelle, Punta del Capo (Gargiulo, pers. comm.), Banco di S. Croce (Bussotti et al., 1999), Porto Rendell (2000; Simeone pers. comm.), Capri-Faraglione di Matermania and Punta di Mulo (Ribera D'Alcalà & Russo, 2001).

I re-surveyed the sites and at Punta Gradelle (Sorrento, D) and Trentaremi (C) I only found a *Sargassum* species (*S. vulgare*) and I computed a LI of 89 %.

In the Annex I, are available the current identifications of the species encountered in the HS where *Sargassum* sp. records have been confirmed.

3.3.2 An overview of the collective decline

The temporal change in the occurrence of Fucales in their historical sites seems to be huge. In more than 84% of historical records we did not find the reported species (Table 10). On a total of 18 Fucales species (15 *Cystoseira* and 3 *Sargassum* species, with an overall of 21 Fucales taxa historically reported) only 9 species were recorded again but with a high percentage of sites in which they have disappeared. The most recurrent species in the past were *C. compressa*, C. *amentacea*, *C. spinosa*, *C. barbata and C. foeniculacea.* In the revisiting campaign only *C. amentacea* and *C. compressa* were found in more than 10 sites of the gulf.

Table 10 : List of species in historical and re-visited sites (HSCP=Historical Sites Currently Present; HSCA=Historical Sites Currently Absent)

Species	**Historical sites (HS)**	**2013-2016 Present (HSCP)**	**2013-2016 Absent (HSCA)**	**Historical Loss Index (LI) (%)**
CA	40	16	24	60
CB	20	0	20	**100**
CBB	1	0	1	**100**
CBR	18	1	17	94
CC	58	18	40	69
CRIN	4	0	4	**100**
CD	4	0	4	**100**
CFF	24	1	23	96
CFu	1	0	1	**100**
CMe	17	4	13	76
CSA	6	1	5	83
CSE	1	0	1	**100**
CS	39	4	35	90
CT	10	0	10	**100**
CZ	9	1	8	89
SA	20	0	20	**100**
SH	19	0	19	**100**
SV	4	1	3	75
Tot	285	46	239	

CB, CBB, CRIN, CD, CFu, CSE, CT, SA, SH have never been recorded during the HS re-survey and therefore for them a Loss Index of 100% can be computed. The other species seem to have a reduced distribution in the gulf, ranging from 60% up to 96%. Although the most sensitive species still exist (*C. amentacea* and *C. mediterranea*), the spatial depletion is dramatic. It is worth to note that the decline of *C. amentacea* reached the lowest Loss Index (60%) in comparison to other less sensitive species (i.e. 69% of *C. compressa*).

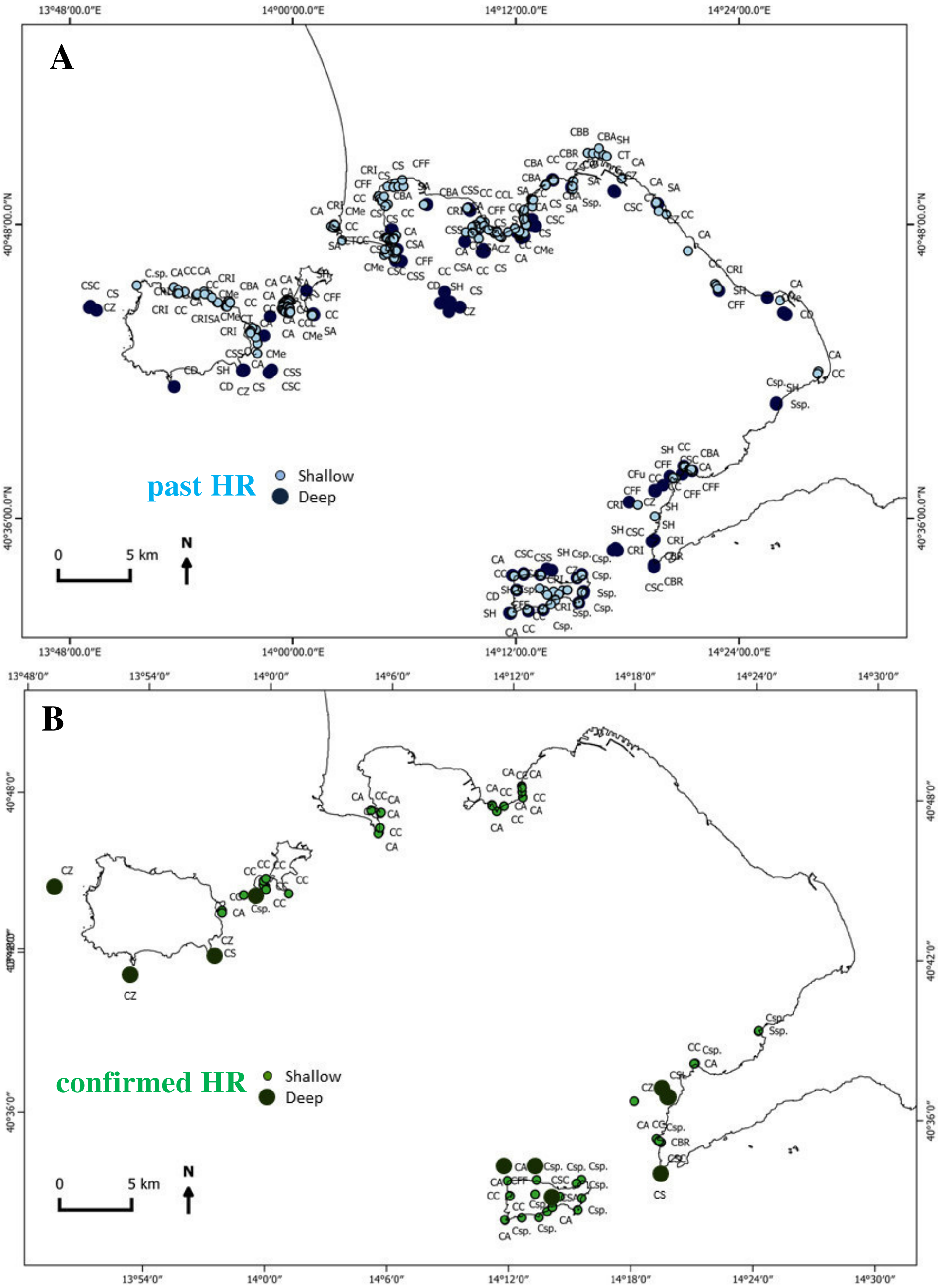


Figure 83 : Historical records present in the Gulf of Naples in the past (A) and currently confirmed to be still present (B)

The status represented in the Figure 83 is much more intense if you consider that most of the green dots are represented by upper subtidal species (CC and CA): in most cases the reported species below the water mark have been totally erased. When the deep species have persisted, the records are confined to the most distant areas from the Bay of Naples (A, D, E Sectors) at least 25 km far from the Naples Harbour.

Anyhow, also among the shallow species the distribution of CA and CC is extremely reduced in terms of number of sites per sector (Table 10). There are many areas depleted of historical records such what it has occurred around Ischia (loss of shallow records in the north, and of deep records in other sides), around Vivara (shallow records), at Baia, Posillipo and from Naples to Castellammare (shallow and deep sites).

From this preliminary study on the decline of fucoids in the gulf (exclusively based on the re-visitation of historical sites) we can conclude that the sectors in which the decline was highest seem to be the northern side of the Ischia Island (Sector A), all the Bay of Pozzuoli (Sector B) and most of the Bay of Naples (Sector C).

Regarding the *Sargassum* spp. occurrence, the only species re-surveyed was *S. vulgare*, the species less recorded in the past among this genus. Also for this species, however, the Loss Index was very high (75%).

3.4 Discussion

Taxonomical identification of Mediterranean *Cystoseira* and *Sargassum* differs according to authors (Thibaut et al., 2015a) because the genera are very complex. Molecular studies unravelling the relationships between species, subspecies, varieties and forms, can help to clarify the taxonomic ambiguities currently existent (Gomez-Garreta et al., 2001; Cormaci et al., 2012; Rodríguez-Prieto et al., 2013; Guiry & Guiry, 2016), despite an attempt (with low resolution) has been already performed by Draisma et al. (2010). This study evidenced with molecular data that *Cystoseira* is a polyphyletic genus and it should be splitted into different clades (3 of them with Mediterranean and north-east Atlantic distribution) but the names of genera has not yet been proposed. Focused research on the diversity and evolutionary relationships of the Mediterraean Fucales is currently more urgent than ever. Knowledge on their evolutionary origin and of their biodiversity is significant and essential for the protection and management of this algal group (Draisma et al., 2010). Despite this still lack of agreement, their loss is rather evident (Thibaut et al., 2005, 2015a, b, 2016).

In the Gulf of Naples, 15 species of *Cystoseira* and 3 of *Sargassum* were reported in the past. Comparing the occurrence in historical sites with the 2013-2016 re-survey, 9 species were no longer observed (CB, CBB, CRIN, CD, CFu, CSE, CT, SA, SH). In addition, other taxa (*C. compressa* included) suffered a decline or became nearly extinct (Table 11); *S. vulgare* the only specie recorded among the *Sargassaceae* was found solely in one historical site, on the Southern coast of the island of Ischia.

The Mediterranean Fucales belong to perennial species that improve the three dimensional architecture of the sea bottom and are able to structurally amplify habitats, hosting a variety of associated species as reported by literature in many other study areas (Molinier, 1960, Sala et al., 2012, Thibaut et al., 2015a,b). On the basis of only these historical scattered data is possible to suppose but still impossible to conclude that the loss of the species leads to a functional extinction, as in deep historical sites we did not find the remarkable forests that other authors found in different regions of the Mediterranean (Ballesteros et al., 1998, 2009). Their regression in terms of cover and abundance means that they cannot play the same ecological and functional roles played in the past (functionally extinct), when they formed dense underwater forests. Despite many past authors simply reported a list of species, some of them tried to quantify their distribution, unfortunately by using qualitative descriptors: 'common’, 'widespread’’, 'monospecific or mixed assemblages', 'less' or 'more frequent species'. Cinelli (1976b) reported that all around the Vivara Island, at 7-10 m depth, *C. crinita* was one of the most abundant species. Funk (1927) described a number of Fucales associations such as *C. compressa* association, *C. compressa-barbata-S. acinarium* association, *C. mediterranea* association, *C. barbata* association, *C. foeniculacea* association, *C. dubia* association and C. *spinosa* var. *compressa* association. In particular, regarding the last association (*C. spinosa*, the most sensitive deep *Cystoseira* species), Funk (1927) stated that 'this association seems to compose the main vegetation of rocky beds, between intermediate depth and 50 m and more'. In addition, Funk, discussing on the '*Cystosira* Gebüsch Formationen' in the Chapter 'Formationsbiologische Glinderung der Vegetation' stated that *Cystoseira* forests (die Cystosiren-Bestände) had massive occurrence ('besondere Formation, wo sie in Masse erscheinen'). The word *Cystoseira* forest ('*Cystosira* Bestände') is frequently used in his monographies testifying the existence of a completely different Neapolitan underwater seascape.

As the historical data that we have analysed only reported their occurrence with limited quantitative data (because scattered and not homogeneous along the coastline) on their abundance, it is therefore difficult to properly estimate their current fate.

We can hypothesize a trend in relation to the number of sites where each species were previously and currently recorded. We can state a ‘local decline’ as the algal occurrence passed to a lower class rank and as ‘extinct’ when it disappeared (Table 11). To verify these two trends it is needed to gather much data on the current occurrence of these species. This can be obtained through the mapping of the shallow species in detail, and checking with SCUBA diving and ROV surveys the occurrence of deeper species in other additional sites, intensifying the surveys especially in sectors where HR were confirmed at present time (i.e. Ischia Island).

Table 11: Status of *Cystoseira* and *Sargassum* taxa based on their reported historical occurrence (HS re-survey) in different periods along the Gulf of Naples

Taxon	**Historical records**	**2013-2016 records**	**Trend**
CA	Very common	Common	Local decline?
CB	Common	Absent	Extinct?
CBB	Very rare	Absent	Extinct?
CBR	Common	Very rare	Local decline?
CC	Very common	Common	Local decline?
CRIN	Very rare	Absent	Extinct?
CD	Very rare	Absent	Extinct?
CFF	Very common	Very rare	Local decline?
CFu	Very rare	Absent	Extinct?
CMe	Common	Very rare	Local decline?
CSA	Very rare	Very rare	Local decline?
CSE	Very rare	Absent	Extinct?
CS	Very common	Very rare	Local decline?
CT	Rare	Absent	Extinct?
CZ	Rare	Very rare	Local decline?
SA	Common	Absent	Extinct?
SH	Common	Absent	Extinct?
SV	Very rare	Very rare	Local decline?

The range of tolerance to disturbance of the genera varies according to the species (Ballesteros et al., 2007). Certain species such as *C. barbata*, *C. compressa* and *S. vulgare* have higher ecological plasticity than others (Falace & Zanelli, 2006). Despite these ecological traits, *C. barbata* has completely disappeared in the study site and also *C. compressa* suffered a decline even if generally resulted to have a common distribution and high tolerance. *C. barbata* is typical of calm waters, repaired bays and coastal lagoons. It was distributed in the sectors A, B, C, and D and frequently reported in the Bay of Naples (Sector C). Those areas (especially Naples Sector) suffered an enormous change along the coastline (coastal development, land reclamation, deployment of artificial barriers); the loss of repaired ad undisturbed zones (calm water and low hydrodynamic conditions, e.g. '[...]ruhingen Wasser bei Capo Posillipo[...]') limited the distribution of species such as *C. barbata*. The lack of undisturbed and calm zones could also be exacerbated by intense maritime traffic in the study area.

Beyond different species-specific hydrodynamics requirements, the success of the reproductive phase probably needs a period of calm water conditions, due to their synchronous spawning (directly sunlight-related) as reported for other species (Vadas et al., 1990; Serrao et al., 1996; Pearson & Serrao, 2006; Schiel & Forster, 2006)

This examples are of valuable interest suggesting a possible role of intense maritime traffic in the Fucales depletion in the study area, leading to an high and long-lasting high hydrodynamic condition during the spring-summer period that overlap with Fucales reproduction time span. Further studies on the relationships between maritime traffic and reproductive time span are needed to clarify the impact of this pression on the fucoids decline.

Changes in the water quality have been already detected in the past for the Sectors B and Sector C by Carrada et al. (1980) when high levels of nutrients were recorded. Even if those values were very high and never recorded yet, we can think that at the end of 70s the increasing urbanization and industrialization in the Sector B together with the lack of sewage treatment could have altered the water transparency and favourite other more competitive algal species (i.e. Sphacelariales and red turf algae).

Results previously obtained (Chapter 2) suggest that the pollution could not be solely responsible for this decline, and other causes may have triggered their depletion. In particular, artificialization of the coast probably stole the natural rocky habitat for these species (Figure 84). The habitat destruction for the artificialization of the coastal line is not coherent with the loss of deep species, with few exceptions (i.e. Nisida and Badessa case, C sector).

Figure 84: Two aerial photos from IGM (1955) and Google Earth (2005) testifying the changes in the coastal development on the North side of the Ischia Island

We can think that the historical reported depths in general could be not always reliable, as in many cases the sampling were done by sight or by nets, trawling dredges (even if the samples depth and techniques were often not specified) and is possible that many records were shallower than those reported.

Anyway for the record between Nisida and Coroglio (Sector C), it is important to remark a huge change in many environmental conditions affecting both shallow and deep species. The case of Nisida and Coroglio is highly symbolic of the entire study area, summarising the high overlay of pressure that the ecosystems have undergone in the gulf. The area is an example of an occurrence of high environmental changes (indirect coastal development additional to nutrient inputs and mussel farming exploitation). The construction of the bridge linking the mainland to Nisida (that around 1936 ceased to be an Island) could have altered the hydrodynamic conditions of the area, shifting to an habitat with strong unidirectional currents to a depositional area (high sedimentation rate). Moreover, in the same area the Coroglio pipeline of waste water (composed by an overfull system along the coastline and a discharge pipeline off the coast) contributed to an important input of nutrients. The historical site of Secca della Gaiola currently known as 'Secca della Badessa' was located exactly in the middle of this area and seemed to be strongly affected to these changes being in front of the sewage discharge. Several (8) were the species described here by Valiante (1883) and Funk (1927) but after the re-survey of HS, no Fucales were recorded yet; during our re-surveys filter feeders were the dominant categories in those sites. Moreover, to exacerbate this complex state, the presence of a mussel farming plant is reported, being few tens of meters far from the HS (Figure 85).

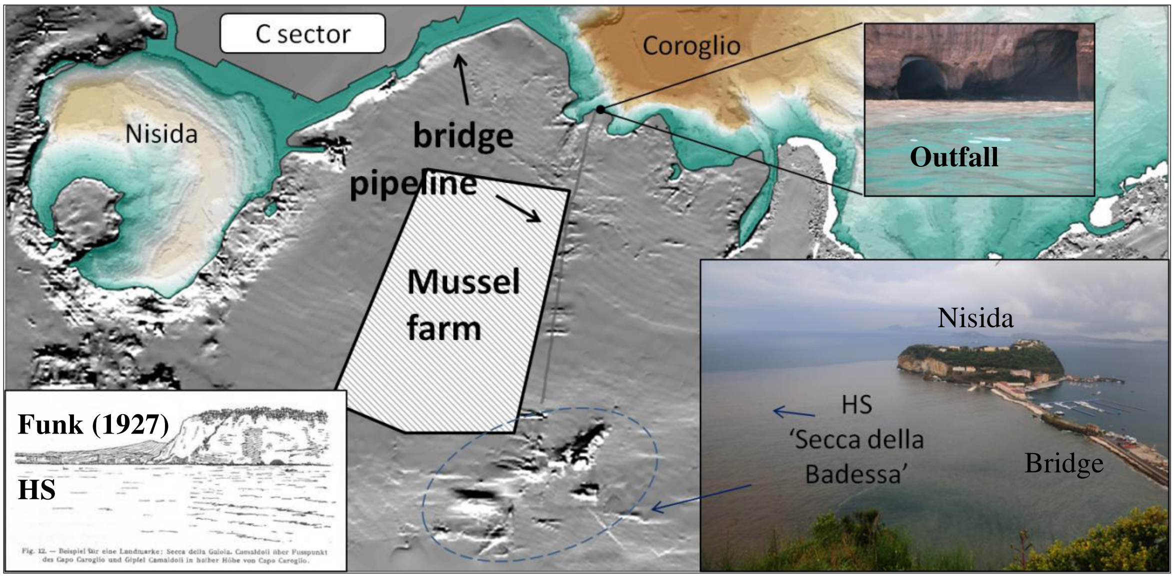


Figure 85: The highly symbolic case of 'Secca della Badessa': HS of Secca della Badessa. Current photo and cartographic support courtesy of Gaiola MPA (C.S.I Gaiola onlus)

Also fishing pressure (trawling, artisanal fishery, illegal mussel harvesting) can impact deep fucoid populations (Thibaut et al., 2015a,b). We can think that this pressure probably was higher in the past, when there were no limitations to fishing activity within the 50 meters depth (i.e. trawling) and could had an impact on subtidal populations (i.e. trawling) possibly leading to extirpations of many of these species.

The Gulf of Naples has undergone cumulative impacts from different human activities (as shown in the symbolic case of Secca della Badessa) that are difficult to disentangle. Anyway these threats, as a general rule at the gulf scale, could be generally considered of lower magnitude far away from the coast.

The comprehensive mapping of the fucoid distribution all along the whole coastline of the Gulf of Naples (Chapter 4) can help to have a better interpretation of current status of Fucales respect to the main pressures that possibly played a significant role in the historical depletion evidenced here.

4. Current distribution of Fucales in the Gulf of Naples and an evaluation of putative causes of decline

4.1 Introduction

Fucales are engineering species that play a relevant role in the ecology of marine ecosystems as they provide habitats, substrate, food, nursery and shelter for associated organisms such as epiphytic algae and a large amount of invertebrates and fishes (Molinier, 1960; Ballesteros et al. 1990a, 1998; Cheminée et al., 2013; Thiriet et al., 2016).

However these ecosystems, mainly in rocky coastal zones, are worldwide under pressure due to increasing human activities and their loss has been recorded in many areas of the Mediterranean basin (Thibaut et al. 2005; 2015a,b). Coastal development and marine pollution seem to be amongst the most important anthropic pressures affecting marine forests. Due to their decline, most of Mediterranean Fucales are listed in the Barcelona' and Bern' Conventions, but few real target actions have been carried out so far for their conservation and management. In addition, a huge lack of knowledge on the current occurrence and distribution of these algae at the Mediterranean scale has to be remarked. Shallow species have received more attention, particularly in the framework of European Directives such as Habitat, Natura 2000, Water Framework Directive (WFD, 2000) (www.ec.europa.eu/environment/nature/legislation; Casazza et al., 2003); Guidance on specie protection and lists of threatened species were published and some indexes were performed by using target species as biological index of water quality (Simboura et al., 2005; Ballesteros et al., 2007; Sfriso et al., 2009; Orfanidis et al., 2011; Bermejo et al., 2013; Orfanidis et al., 2014). Deep taxa, on the opposite, have been rarely investigated (Tina et al., 1994, Ballesteros et al., 1998, 2009) due to the depth of their settlement, the complexity of this group of brown algae and the lack of taxonomic skills, that made challenging their study. To achieve the conservation and management of these species, the knowledge on their occurrence and distribution is therefore a crucial step.

The re-visitation of historical sites where *Cystoseira* and *Sargassum* species were recorded since 19th century (Chapter 3) highlighted a general loss both in their richness, distribution and abundance. Their decline together with the lack of an updated detailed bionomic map on their distribution in the Gulf of Naples drove me to fill this gap of knowledge.

The purpose of this work was to conduct a survey in the gulf at different depths and with different techniques to monitor their distribution along the 5 sectors that are affected to different pressures (Chapter 2), in order to detect their current status, establish a base reference-line for future assessment, and to propose a better management of the marine spatial planning in order to prevent their local extinction.

In the Gulf of Naples despite the existence of 4 MPA (Marine Protected Area) and 1 ZTB (Zona di Tutela Biologica), no dedicated cartography exist on these algae and generally they are cited such as *Cystoseira* sp. or *Sargassum* sp.; in addition the existent bionomic maps of MPAs in the gulf only refer to Photophilous Algae (AP), without any distinction among encrusting, turf forming erect algae or *Cystoseira* and *Sargassum* associations (Bellan-Santini et al., 2002). Therefore, it is of great importance to increase the knowledge on the stands that these species can form, generating and updating maps. This current assessment will be fundamental to detect any change over time of these species in the next future.

With the aim to fill the lack of knowledge on their current occurrence in the Gulf of Naples and to increase the knowledge on the occurrence of deep marine forests, up to now never recorded, I conducted a detailed three years survey (2013-2016) around the coastline of the Gulf of Naples.

4.2 Material and methods

4.2.1 Study site

I divided the Gulf of Naples in 5 different sectors (Figure 86). The division has been decided on the basis of geographical significant points: Phlegrean Islands (A, Ischia, Procida and Vivara Islands), Pozzuoli Bay (B, from Torregaveta to Nisida), Naples Bay (C, from Nisida to Vico Equense), Sorrento peninsula (D, from Vico Equense to Punta Campanella) and Capri Island (E). Main reference points on the coast have been marked in the map (Figure 86). The entire coastline development of the Gulf of Naples from Torregaveta (40°48'48.69"N; 14° 2'40.47"E) to Punta Campanella (40°34'4.53"N; 14°19'34.64"E) has been monitored.

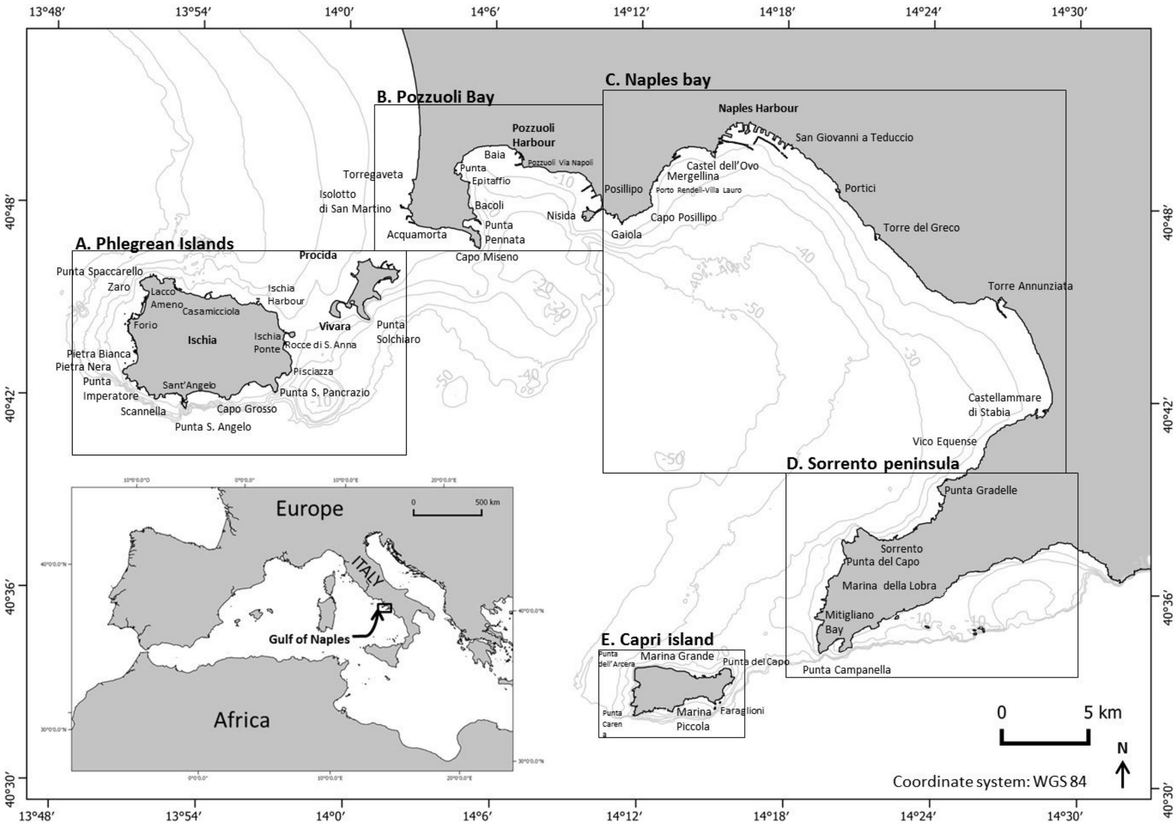


Figure 86: A map of the studied area: the Gulf of Naples (South Tyrrhenian Sea, Italy) and the five sectors in which the study area has been divided

4.2.2 Data collection

The distribution of the brown algae belonging to the genuses of *Cystoseira* and *Sargassum* was investigated during field surveys by snorkelling, apnoea, kayaking and scuba diving from 2013 to 2016. The entire coastline development of the Gulf of Naples from Torregaveta (40°48'48.69"N; 14° 2'40.47"E) to Punta Campanella (40°34'4.53"N; 14°19'34.64"E) has been monitored. For the shallow records (from 0 to 5 m) of the five sectors of the gulf (A, B, C, D, E), I used a 4,85 m long kayak, travelling very close to the coast and using a sampling unit of 25m (scale 1:2,500); within this stretch length, the continuity of the populations was evaluated according to Ballesteros et al. (2007) in six classes: 0 (absent, no observed individuals), 1 (rare scattered individuals), 2 (abundant scattered individuals), 3 (abundant patches of dense stands), 4 (almost continuous belts), 5 (continuous belts). The kayak was also equipped with a handmade bathy-scope to detect the occurrence of target species under the water mark (Figure 87) and a portable GPS device (Garmin Etrex 20x).

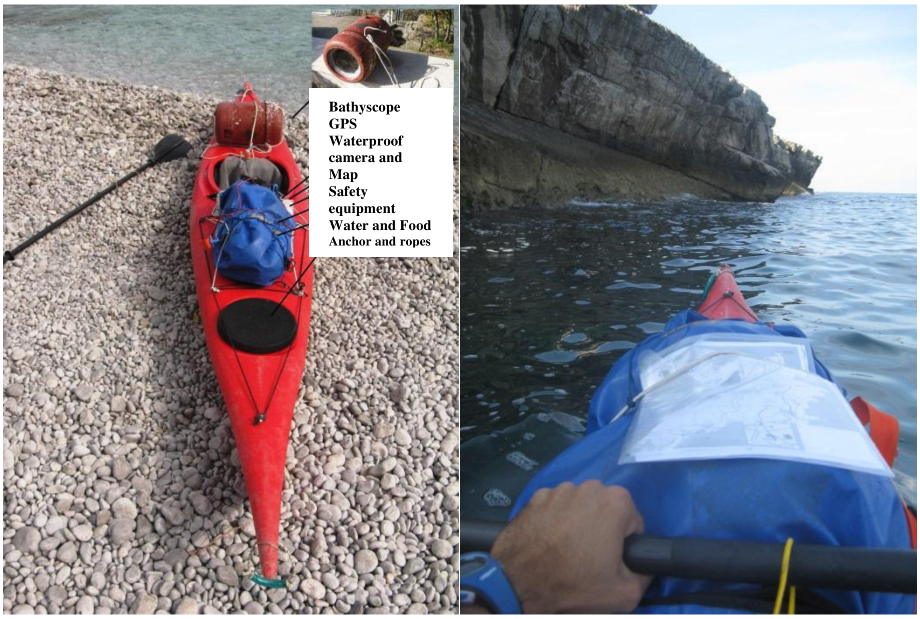


Figure 87: Equipment used during the kayak surveys

Deep sites (from 5 to 50m depth) have been surveyed by S.C.U.B.A. diving during *ad hoc* SZN surveys for Sector A; staff of diving clubs and Marine Protected Areas (MPAs) helped me in the other sectors of the gulf.

Recorded deep populations were geo-localised as points. The abundance of shallow and deep species was estimated by Visual Census (VC); six classes were identified: 0 (absent, no observed individuals), 1 (rare scattered individuals), 2 (abundant scattered individuals), 3 (abundant patches of dense stands patches of some dm^2 of cover), 4 (scattered populations, several patches, covering several m^2), 5 (dense population, continuous population during the survey). The abundance of the Fucales order encountered in each site was derived from the maximum value of the most abundant species class; an ecological value of relevance (Relative site value, RSV) was assigned to each site calculated as the product of the abundance of the Fucales with the species richness.

For records deeper than 50 m, HD videos from technical divers, documentaries and movies were also analysed. In order to increase the sampling effort and gather the maximum amount of information, I developed a Citizen Science project named ‘Progetto Fucales: chi le ha viste?’ (CiSci-PF) with the aim to collect information on current presence of Fucales in the gulf. The project was addressed to all the stakeholders of the sea with specific focus to underwater photographers, fishermen and kayakers.

Species were identified in the field, if possible (avoiding to collect rare and isolated species); otherwise doubtful specimens were collected, stored in -20 °C and identified in the laboratory according to Gomez-Garreta et al. (2001), Cormaci et al. (2012), Rodríguez-Prieto et al. (2013). Vouchers of samples collected in the framework of this study were deposited in the Grech’s Herbarium, hold at the Stazione Zoologica di Napoli (Integrative Marine Ecology Department, Villa Dohrn, Ischia) together with the G.I.S. and Microsoft Excel databases and the linked *in vivo* photo (at least 1 sample per each species). I also collaborated for another PhD project focused on genetics and connectivity of Fucales in the Gulf of Naples collecting, identifying and preserving most of the samples.

A spatial database, named FuCarT (Fucales CarTographyc database), including historical records, current distribution of shallow and deep Fucales and all the georeferenced territorial data, was realized (Figure 88 A, B). The open-source software QGIS 2.8.6–Wien was used to implement this database. These data come from partially freeware (with low resolution data or Web Map

Services) open source databases (http://www.pcn.minambiente.it/GN/accesso-ai-servizi/servizi-di visualizzazione-wms) and data collected during this thesis work (i.e.: data of fishing distribution, spatial use of the coast). The database is quite simple and intuitive. All the available information collected by literature (Historical Records, Chapter 3) and current Fucales mapping (this Chapter) is included in the database spatially represented by respectively dots and lines vector layers. By clicking on the the QGIS info tools data for each dot or line are displayed. Attribute Table of QGIS summarize details of the HR information (dots): species code recorded, bibliographic reference, Depth, Locality and Authors comments (if available) (Figure 88; Figure 89). A detailed Digital Terrain Model (DTM) of the sub-area Nisida-Posillipo was available thanks to Gaiola MPA in the framework of the MedPAN project 'A territorial analysis for the integrated management of the Posillipo Coastline'.

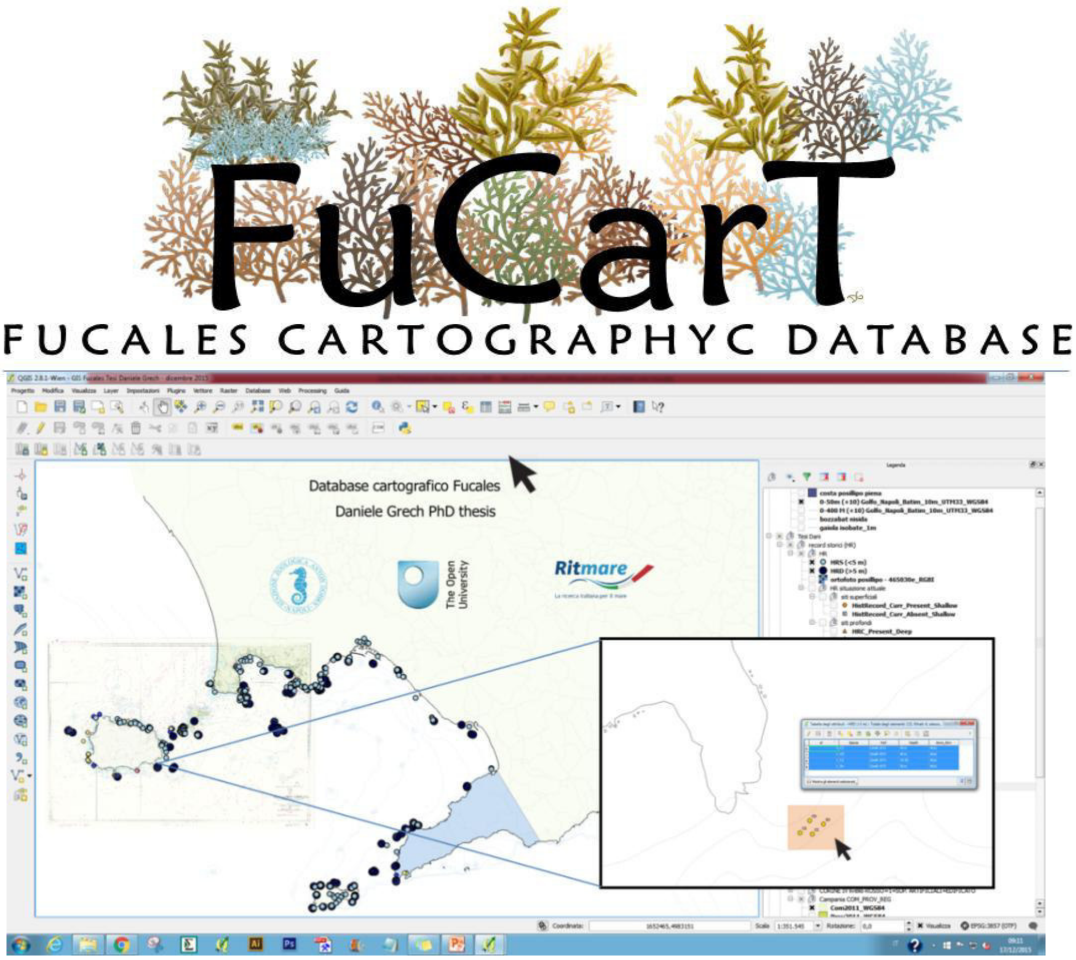


Figure 88: Home screen of the Fucales CarTographyc database (FuCarT)

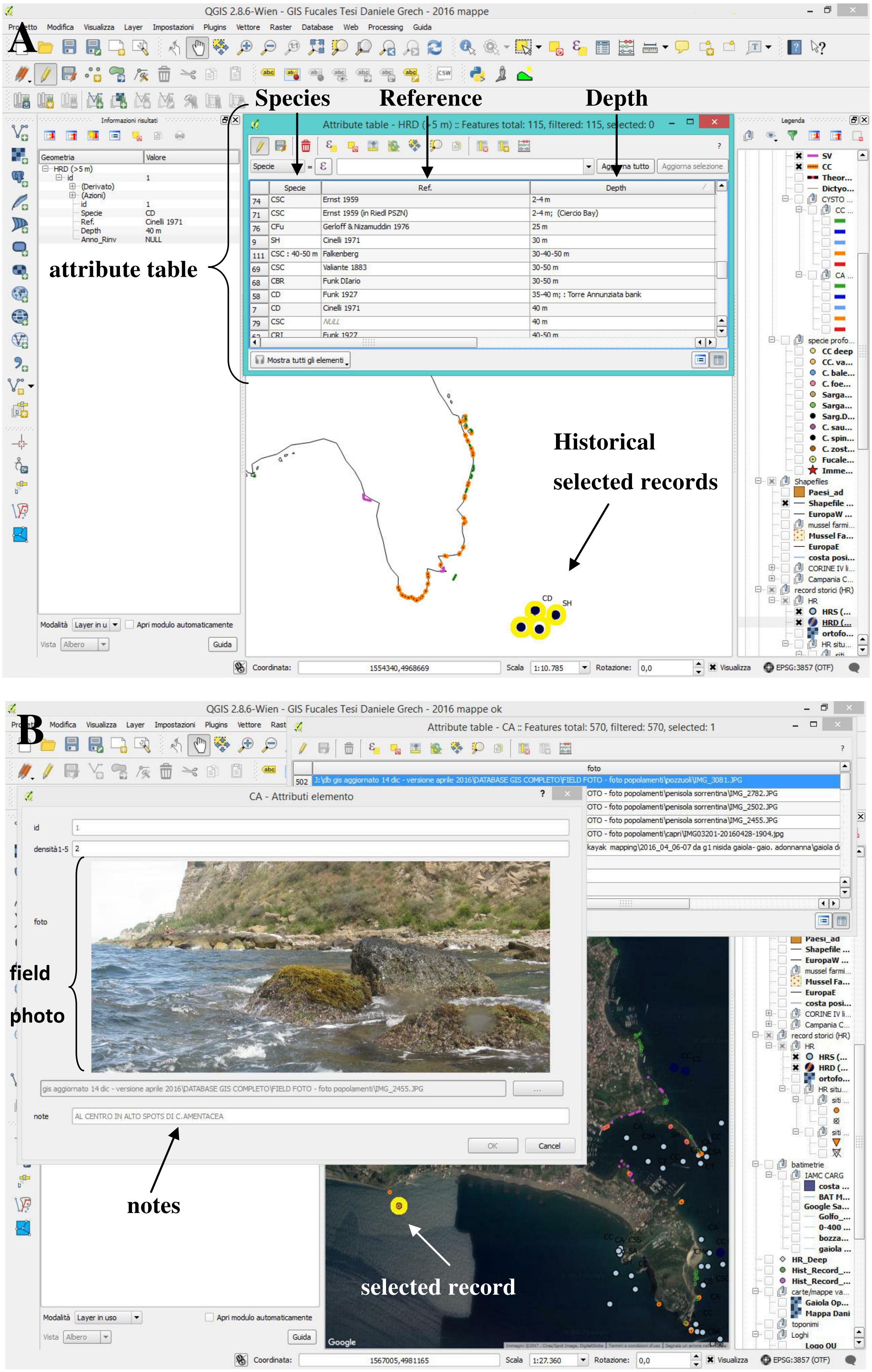


Figure 89: Details of FuCarT database. Attribute table for HR (A) and current occurrence of Fucales (B)

Lines (current Fucales mapping) display the occurrence of the species with different colours and layers. The attribute Table of QGIS shows Species code recorded, GPS coordinates, Depth, Locality, useful Comments and Density Value (if available). Moreover an attached field photo is available for most of the assemblages of different localities, in order to have a photographic reference baseline of the further assessments. Species code recorded, bibliographic reference, Depth, Locality and Authors comments (if available). (Figure 88, Figure 89). In the provided maps of shallow species, in order to obtain a better display, the GIS layers with lower occurrence were represented at highest levels, while the lower level was occupied by the most widespread species. As the current records of lower subtidal (deep) species were not continuous, their georeferenced occurrence has been reported as points on maps. These data are displayed per each species of the gulf. The distribution of shallow species has been represented in maps along the coastline, overlaying also the location of sewage discharges along the coast, as reported in literature by many authors (Thibaut et al., 2005; 2014; 2015a,b). For Phlegrean islands (A) the exact location of those points has been retrieved from literature (Zucco, 2003) while for the other sectors the points corresponded to personal observations. The FuCarT database is conceived as a starting point for an integrated approach devoted to coastal systems management and conservation; the geographical localization of the species should be integrated by water and ground chemical-physical parameters, and detailed and comprehensive maps of pressures. In our purpose it should be part of a data based management system in order to provide by queries detailed and update information on benthic vegetated systems in the Gulf of Naples.

4.3 Results

The 2013-2016 survey of *Cystoseira* and *Sargassum* species in the Gulf of Naples highlighted the current occurrence of 15 taxa in total (11 species), both in shallow and deep zones, from upper subtidal zone down to 50 m depth. A complete list of the species recorded is available in Table 12. Respect to Chapter 3 results, 2 species that where no longer observed in the HS, were recorded during this survey (CRI and SA).

The highest diversity and cover of Fucales were recorded around the Ischia Island (sector A) on its south-west side, from Punta Imperatore to Sant'Angelo, where the slope of the coast line was less steep (Figure 90).

In the present study, I reported for the first time the occurrence of *C. crinita* around the island of Ischia as in previous Funk's publication (1927) it was misidentified with *C. brachycarpa*. During my surveys *C. brachycarpa* was recorded in shallow habitats in sectors A and E and listed among lower subtidal species in sectors A, D and E. This species was the most abundant taxon below the water mark in the entire study area.

Table 12: List of the taxa recorded in the Gulf on Naples in the time lag 2013-2016

Species	Code
Cystoseira amentacea **(C. Agardh) Bory the Saint-Vincent**	**CA**
Cystoseira brachycarpa **J.Agardh**	**CBR**
Cystoseira compressa subsp. pustulata **(Ercegovic) Verlaque**	**CCp**
Cystoseira compressa **(Esper) Gerloff & Nizamuddin subsp.** ***compressa***	**CCc**
Cystoseira crinita **Duby**	**CRIN**
Cystoseira foeniculacea **(Linnaeus) Greville**	**CF**
Cystoseira foeniculacea **(Linnaeus) Greville f.** ***foeniculacea***	**CFf**
Cystoseira foeniculacea **(Linnaeus) Greville f.** ***latiramosa*** **(Ercegovic) Gómez Garreta, Barceló, Ribera et Rull Lluch**	**CFl**
Cystoseira mediterranea **Sauvageau**	**CMe**
Cystoseira sauvageauana **Hamel**	**CSA**
Cystoseira spinosa **Sauvageau**	**CS**
Cystoseira spinosa **Sauvageau** ***var. spinosa***	**CSs**
Cystoseira spinosa **Sauvageau** ***var. compressa Cormaci, Furnari, Giaccone, Scamacca & Serio***	**CSc**
Cystoseira zosteroides **(Turner) C.Agardh**	**CZ**
Sargassum acinarium **(Linnaeus) Setchell**	**SA**
Sargassum vulgare **C.Agardh**	**SV**

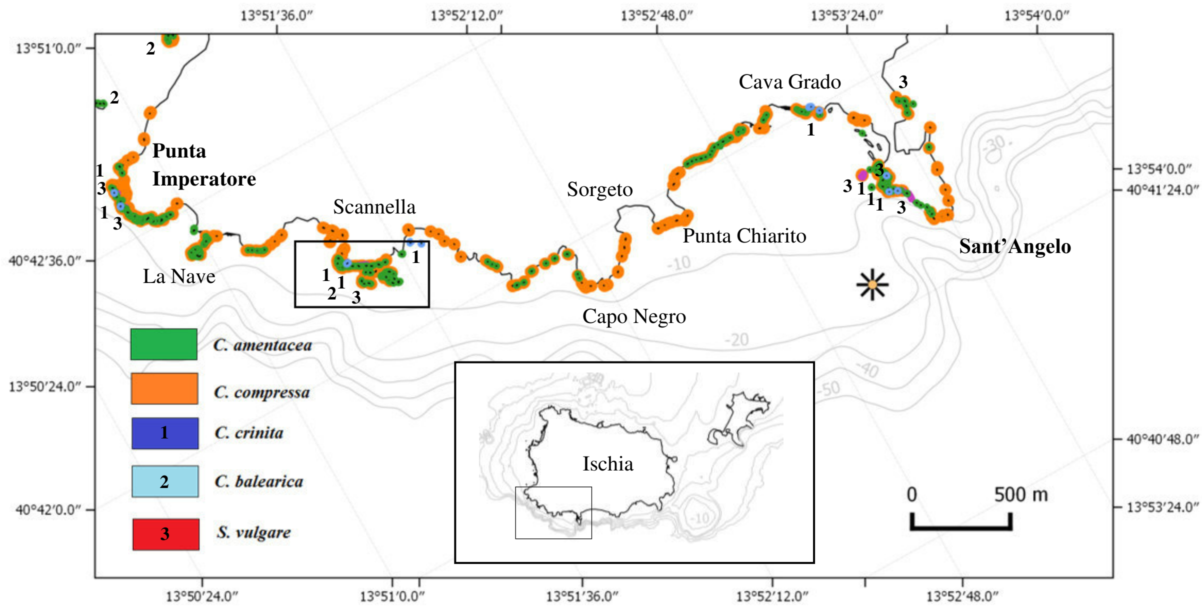


Figure 90: Map of the Fucales distribution on the west side of Ischia, from Punta Imperatore (on the left) to Sant'Angelo (on the right). In the frame the location of Scannella rock-pools, where the highest biodiversity of the gulf is reached

During the survey, two forms of *C. foeniculacea* were recorded: *C. foeniculacea* forma *foeniculacea* and *C. foeniculacea* forma *latiramosa*. Due to the difficulty to distinguish the two forms *in situ*, in some cases the specimen was identified as *C. foeniculacea* (especially when it was in very young stage or in bad conditions).

Specimens of the highly sensitive species *C. spinosa* were found in A, D, E sectors, although with very low abundances. Generally deep *Cystoseira* spp. have been recorded below 15-20 (in some sites even below 25) meters, except for the area between Pietra Nera and Baia di Citara (Ischia, A sector) were many specimens of the species *C. brachycarpa* and some *C. spinosa* occur from 0 to 10-12 m. *Cystoseira compressa* var. *compressa* in this site was occasionally found below water mark, with few isolated specimens between 9 and 15 m.

An interesting contribution was given by citizens involved in the Progetto Fucales (Figure 91). Even if a low number (N=26) of people take part of the project, we received 29 replies from underwater photographers (54%), kayakers (15%), fishermen (12%) and others (19%). Among them, the percentage of records consistent and useful for the PhD thesis was 48% even if an additional 28% well recognized the species but outside the study area. Only a lower percentage

(24%) provided a wrong identification (fucoids were mistaken with other brown erect species such as Sphacelariales or Dictyotales).

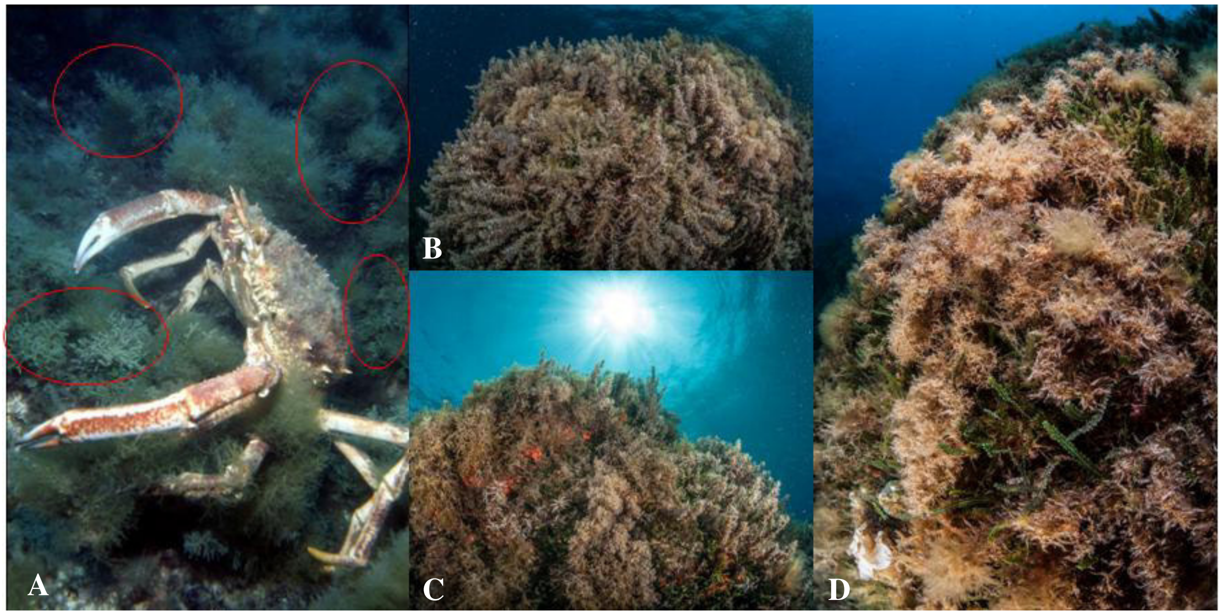


Figure 91: Pictures including Fucales specimens, gathered through the citizen project (A: Giampiero Liguori, B, C, D: Edoardo Ruspantini)

In next paragraphs the current distribution of shallow and deep Fucales per each sector will be displayed in georeferenced maps (Annex II and Table 14). The sewage outfall locations along the coastline of Phlegrean Islands have been superimposed to the distribution maps.

Sector A: Ischia Procida and Vivara

A detailed list of sites of the shallow species recorded in this sector was reported in the Annex II. Among them, 7 species occurred in the upper subtidal fringe while 8 were deeper. Among the shallow records (Figure 92), *C. compressa* var. *compressa* was the most widespread species among *Cystoseira* genus; in particular, this species was completely lacking on the north side of the Ischia Island, between Punta Molino and Lacco Ameno. *C. compressa* var. *pustulata* has been recorded in rock-pools at Zaro, Punta Imperatore and Scannella.

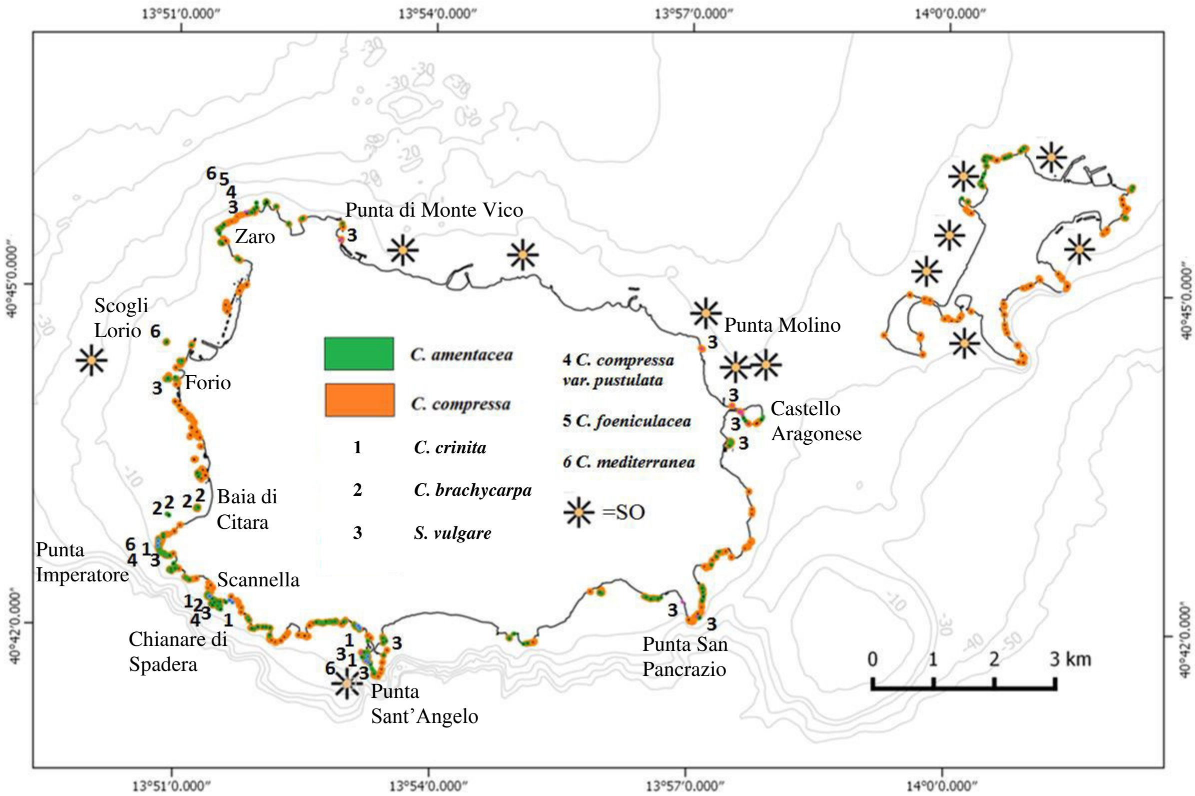


Figure 92: Distribution of *Cystoseira* spp. along the coasts of Phlegrean Islands (Sector A). SO=Sewage outfall

Cystoseira amentacea distribution was very fragmented and generally mixed with *C. compressa* var. *compressa*. In the North side of Ischia (from Castello Aragonese to Punta di Monte Vico) it was currently completely lacking. East and west population were completely isolated by the presence of sandy beaches and the subsequent construction of harbours and marinas, overlaying the natural rocks. However, *C. amentacea* reached along the coast of Ischia its highest abundance in the gulf, mainly on the south-west side of the island: Punta Imperatore, Scannella, La Nave, Chianare di Spadera, Scogli Lorio (Figure 90, 92).

A quantitative evaluation of *C. compressa* var. *compressa* the most abundant species around the Ischia Island is reported in Figure 93.

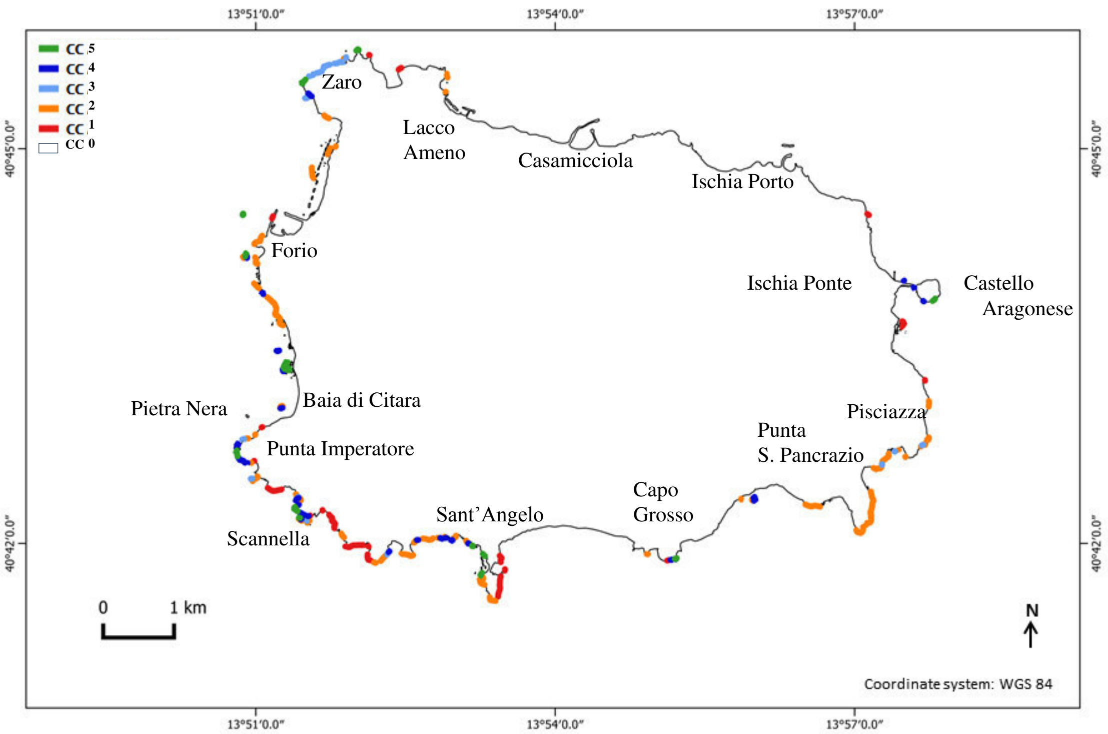


Figure 93: Distribution and quantitative evaluation of *C. compressa* var. *compressa* populations around the shallow costs of Ischia Island. Colours correspond to six classes: 0 (absent, no observed individuals), 1 (rare scattered individuals), 2 (abundant scattered individuals), 3 (abundant patches of dense stands), 4 (almost continuous belts), 5 (continuous belts).

A quantitative evaluation of *Cystoseira amentacea*, the most sensitive species around the Ischia Island is reported in Figure 94.

The two species *C. amentacea* and *C. compressa* var. *compressa* were the only taxa recorded at water mark around the islands of Procida and Vivara (Figure 92), while other two shallow species of *Cystoseira* were found around Ischia: they were *C. crinita* and *C. brachycarpa* (Figure 92,95). Their abundance was extremely low all along the coastline.

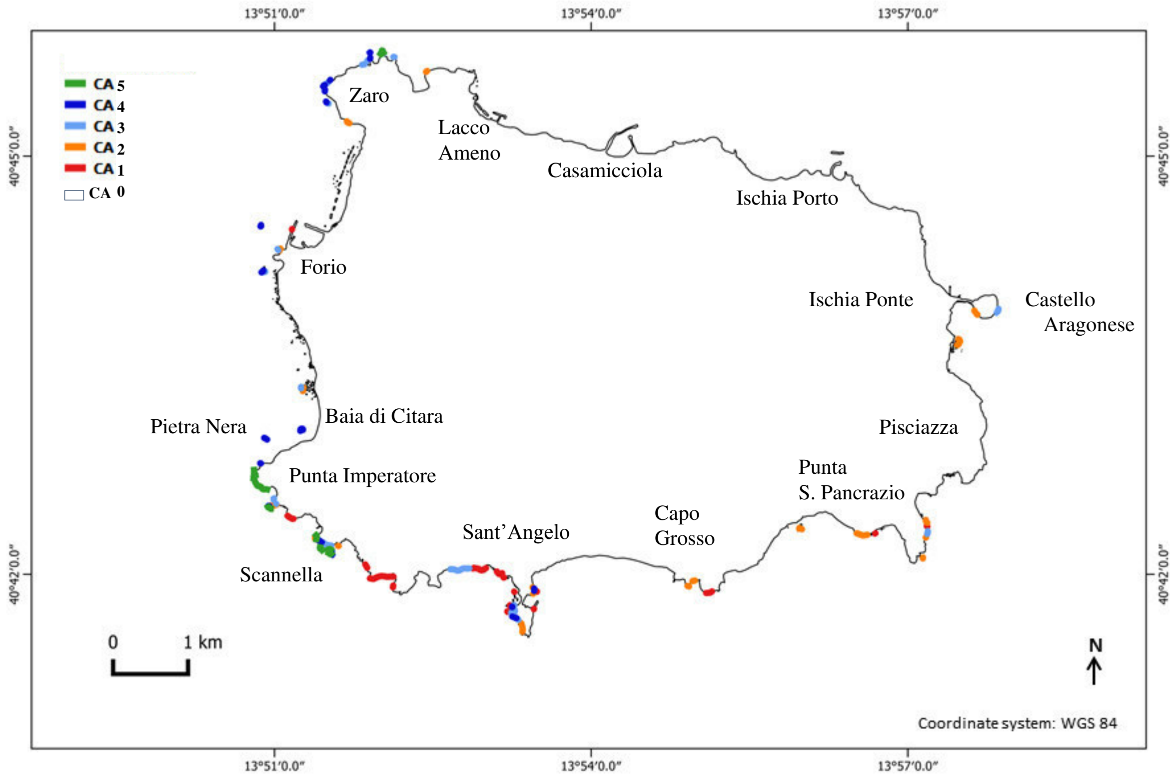


Figure 94: Distribution and quantitative evaluation of *C. amentacea* populations around the shallow costs of Ischia Island. Colours correspond to six classes: 0 (absent, no observed individuals), 1 (rare scattered individuals), 2 (abundant scattered individuals), 3 (abundant patches of dense stands), 4 (almost continuous belts), 5 (continuous belts).

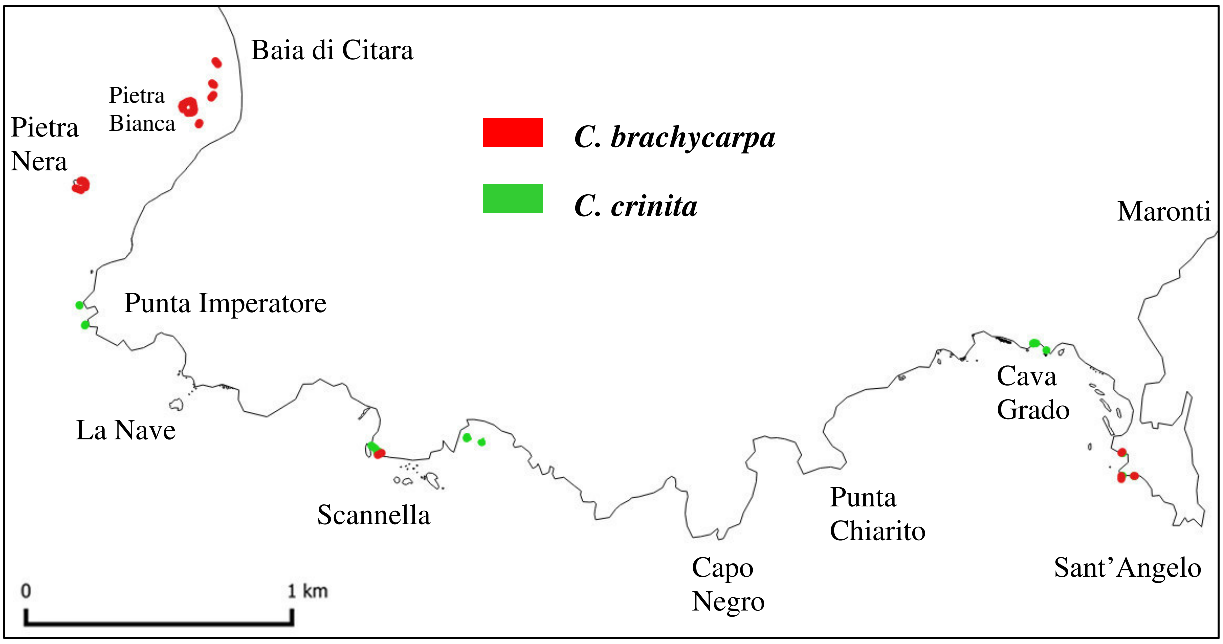


Figure 95: Occurrence of *C. brachycarpa* (light blue) and *C. crinita* (dark blue) on the south western coastline of Ischia Island.

S. vulgare was recorded in shallow habitats of this sector A (Figure 92). It has a generally spotted distribution: few specimens in about 20 sites. A peculiar and dense forest of *S. vulgare* was present along the south and sheltered side of the Castello Aragonese (the bay between the Castello Aragonese and Rocce di Sant'Anna), where CO_2 vents decrease the pH of the water down to 6.7 (Hall-Spencer et al., 2008; Porzio et al., 2011; Chiarore et al., 2012). In this location the populations were characterized by very long axis (more than 50 cm) thriving also in artificial rock-pools among breakwaters, well developed between March and June (personal observations). This species occurred also at Rocce di S. Anna, Lacco Ameno, Zaro, Scogli Lorio, Sant'Angelo and Scannella. In this latter site located on the south of Ischia, the most interesting system of natural rock-pools of the gulf was discovered and described. Three main rock-pools (A, B, C) were distinguished and the largest pool (A) extended for an area of about 9.4 m^2 (Figure 96). Here the highest biodiversity of Fucales with 6 censed taxa was recorded (Table 13). The highly sensitive species *C. crinita* has been found in all the three rock-pools.

Table 13: List of species recorded in the three Scannella rock-pools

Rock-pool A:	**Rock-pool B:**	**Rock-pool C:**
C. amentacea	*C. amentacea*	*C. amentacea*
C. brachycarpa	*C. crinita*	*C. compressa*
C. compressa var. *compressa*	*S. vulgare*	*C. crinita*
C. compressa subsp. *pustulata*		*S. vulgare*
C. crinita		
S. vulgare		

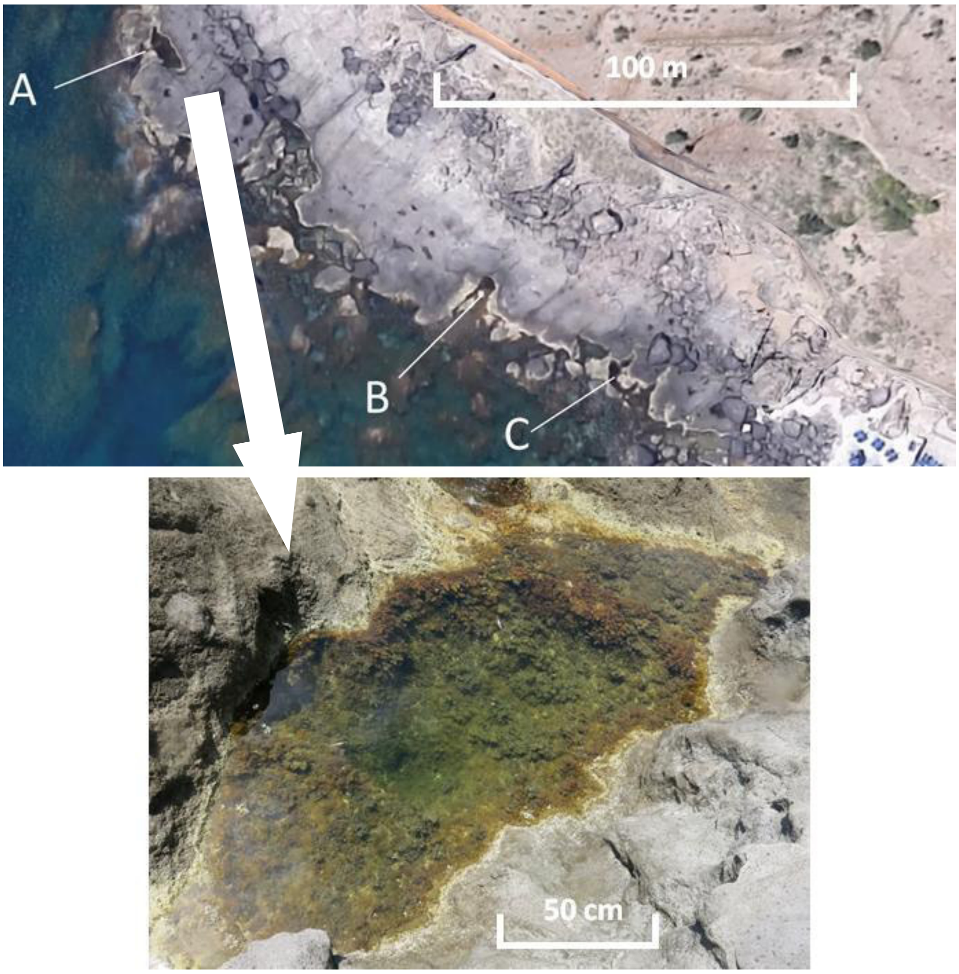


Figure 96: Satellite Image from Google Earth showing the three largest rock-pools censed at Scannella (up) and a picture of the largest pool A (bottom)

In Table 14 a list of lower subtidal sites where *Cystoseira* and *Sargassum* species, is reported.

Among the deep species the occurrence of scattered and isolated plants of *Cystoseira foeniculacea* was recorded at Scannella, Zaro and Capo Grosso (Figure 105). We have to mention the record on the southwest side of the island (Pietra Nera, off Baia di Citara), of the unique *Cystoseira* ‘forest’ recorded in the gulf. This site was represented by a tuff emerging rock with a submerged platform of about 4,000 m^2, less than 1 km far from the beach and located on a 15-20 m depth sandy bottom (where is settled a dense *Posidonia oceanica* meadow); from 0 to 15m depth the rock was covered by a dense *C. brachycarpa* population (Figure 97, 102). Further findings of this species were those reported for Bell’Ommo, Il Faraglione, La Nave, Pietra Bianca, Punta Imperatore, Punta Spaccarello, Scannella (Figure 102), in Ischia.

Cystoseira spinosa (Figure 106, 107) was currently present with few individuals in many sites along the island (Table 14): Banco d'Ischia, La Nave, Pietra Nera, Punta Imperatore, San Pancrazio, and Scannella.

C. zosteroides has been reported for Secca di Forio, Sant'Angelo (Figure 109).

Sargassum vulgare is widespread around Ischia (Bell'Ommo, Capo Grosso, La Nave, Pietra Bianca, Punta Imperatore, Punta Spaccarello, Scannella; Figure 111).

Deep populations of *Sargassum acinarum* were found at Il Faraglione, Punta San Pancrazio and Scannella (Figure 110) and unidentified *Sargassum* sp. were reported for Secca delle Formiche and many other sites around Ischia (Figure 112).

Comprehensive maps of all the deep species at the gulf scale are represented in the Figures 102-112, at the end of the last shallow map of sector E.

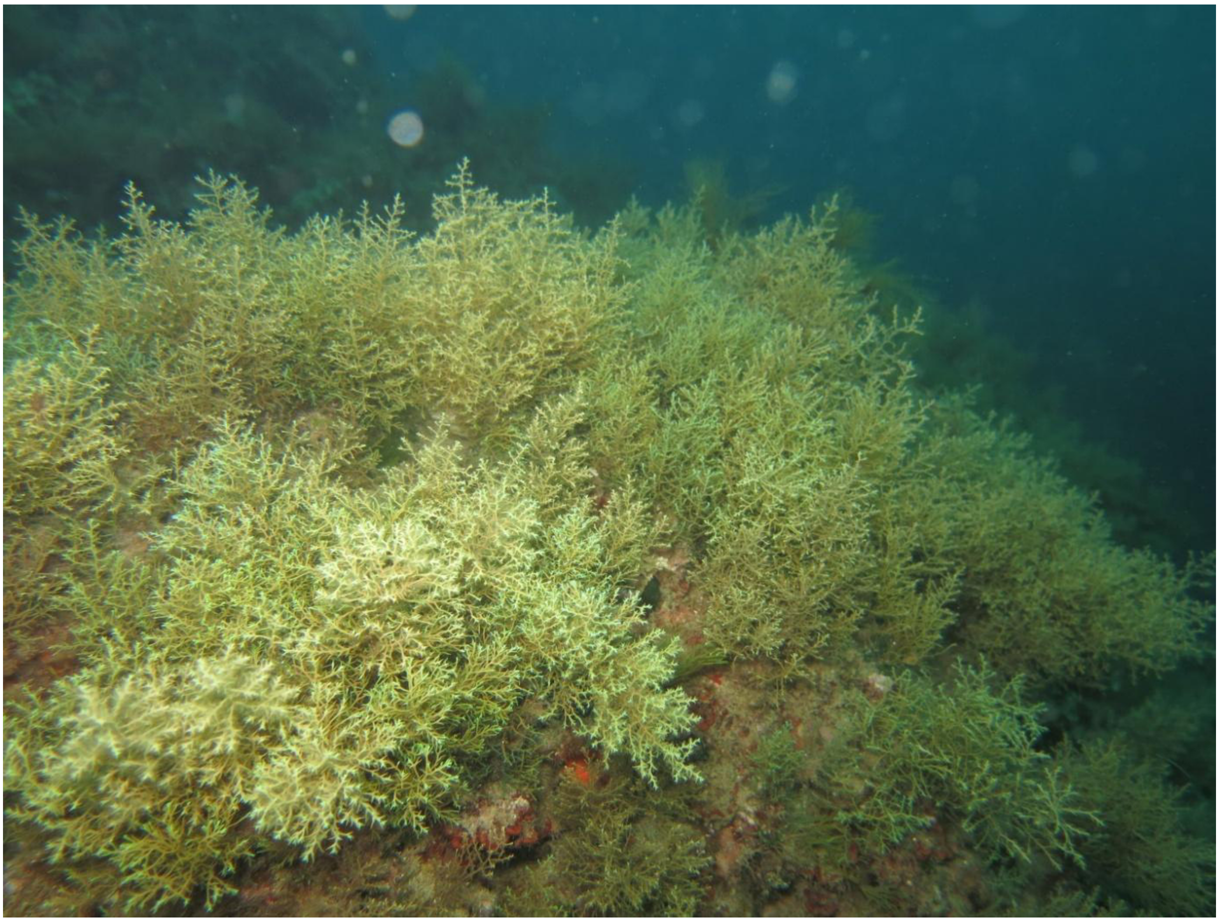


Figure 97: *C. brachycarpa* forest at Pietra Nera

Sector B: Pozzuoli Bay

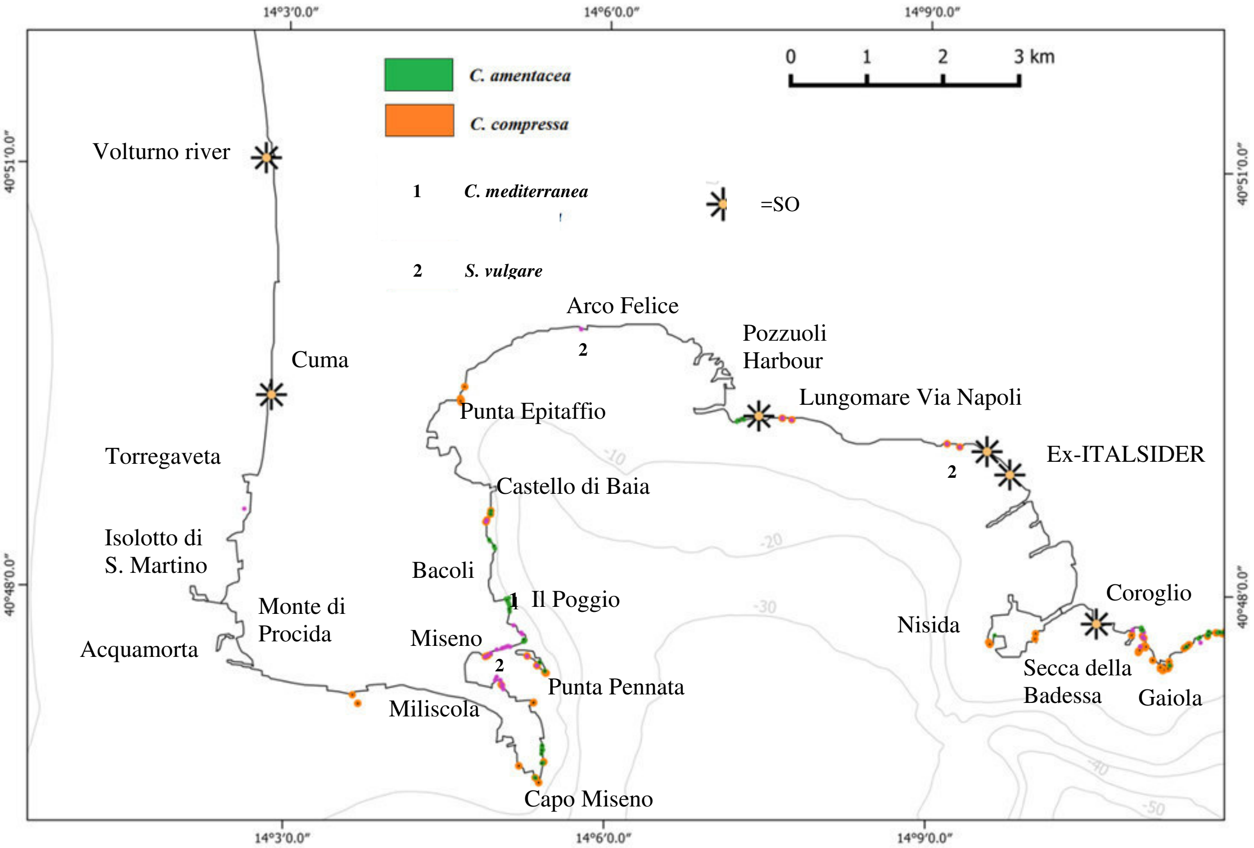


Figure 98: Fucales distribution in Pozzuoli Bay. SO=Sewage outfall

In this sector, 4 species occurred in the upper subtidal fringe (Ca, CCc, CA, CMe, SV) while no deep species have been encountered. The east part of Pozzuoli Bay (Capo Miseno) hosted the second most important population of Fucales in the gulf, mainly *C. amentacea* and *compressa*, with spots and brief but dense belts of *S. vulgare* (Capo Miseno-Il Poggio). Also few specimens of *C. mediterranea* were reported at Il Poggio, close to Bacoli (Figure 96).

In this sites thrived the north-westernmost spots of *C. compressa* of the gulf (in artificial rocks of Miliscola beach, western from the Acquamorta closed lagoon) while *C. amentacea* was absent in the entire Monte di Procida coastline. The first populations of this latter species have been found close to Capo Miseno, in front of the white lighthouse.

In 2013, in the inner part of Pozzuoli Bay (east of Capo Miseno) was present a dense belt of *C. amentacea*, documented by Mulas et al. (2013). Most of that belt has been buried by tons of tuff because of a landslide which affected the site in March, 2015, changing the coastline landscape. Relict population still exist northward and southward of landslide, but has been reduced at least of 50%.

S. vulgare was quite abundant in the Baia di Miseno, Punta Pennata, Il Poggio, and Marina Grande di Bacoli. In the MPA of Baia, a little population of *C. compressa* was present at Punta Epitaffio. No other species has been reported, apart for sporadic *S. vulgare* spots close to Arco Felice railway stop. Surprisingly, close to a very degraded area, 700 m to Pozzuoli harbour, spots of *C. amentacea* and *C. compressa* existed, exactly between Rione Terra and Lungomare via Napoli (40.8203 N; 14,1204 E). Other spots of *S. vulgare* and *C. compressa* were present in fringing rocky boulders here. The last spots of these species were about 1 km distant from the first pontoon of the ex-Italsider industrial plant.

Buoyant axes of *S. vulgare* have been collected close to Torregaveta (North-western limit of the B sector), an area interested by general moderate-high pollution and where dense mussels communities completely cover all the rocks.

Regarding the deep species, notwithstanding the SCUBA diving surveys, no subtidal species were found.

Sector C: Naples Bay

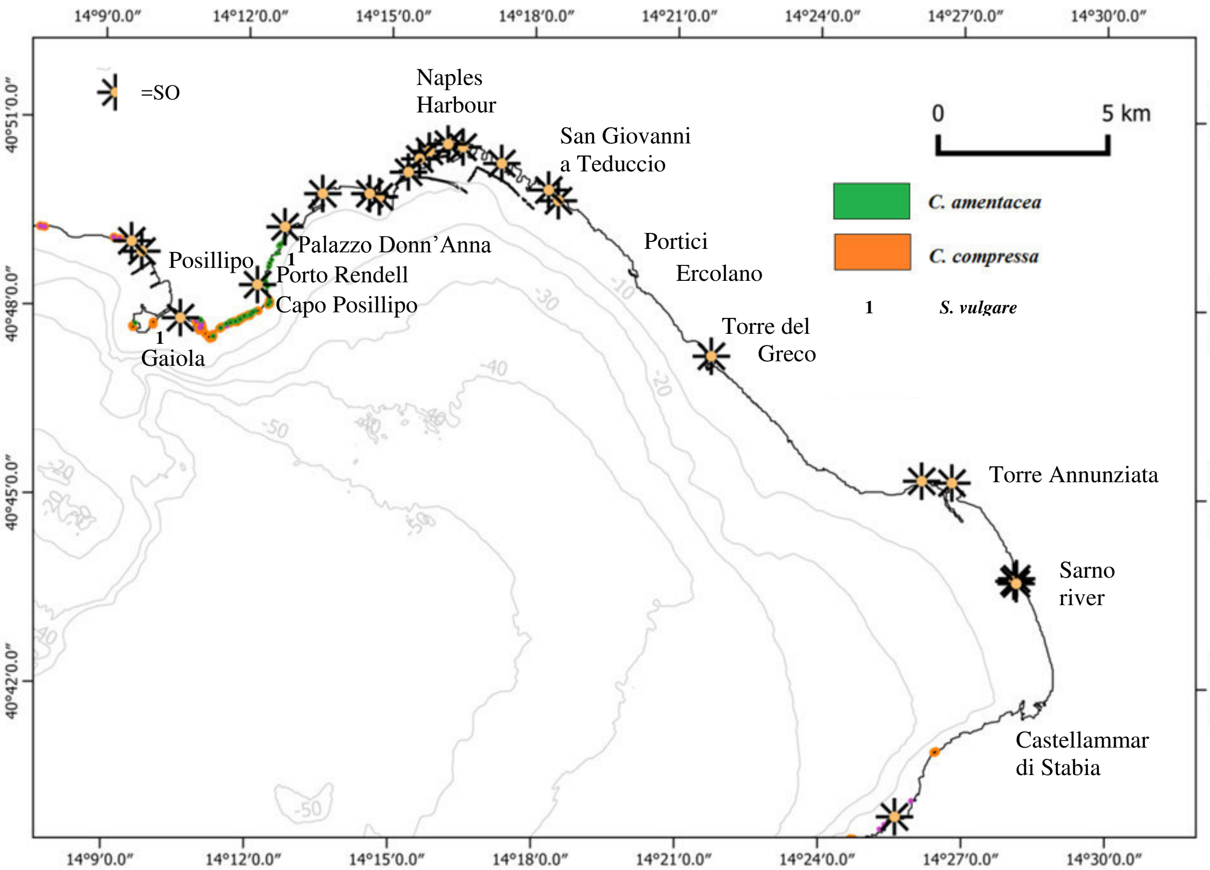


Figure 99: Fucales distribution in Naples Bay. SO=Sewage outfall

In the Sector C, 3 shallow species (CA, CC and SV) and no deep species were found. In that sector there were still limited portions of coastline with well-developed belts of *C. amentacea* (few meters) along Posillipo, especially close to 'Sud Italia' and 'Rocce Verdi' zones (Figure 97).

Sargassum vulgare was abundant in Baia di Trentaremi but spotted along the Posillipo coastline. Despite the existence of many rock-pools in the area, no other species have been reported. Many suitable rocks for shallow Fucales have been found between Torre del Greco and Torre Annunziata, but they were totally covered by mussels.

Notwithstanding the high number of SCUBA diving surveys, no subtidal species were found. It is important to remark the high occurrence of filter feeders, especially sea fans and sea squirts (e.g. *Leptogorgia sarmentosa* and *Halocynthia papillosa*) and sciaphilous algal species, in very shallow depth.

Sector D: Sorrento peninsula

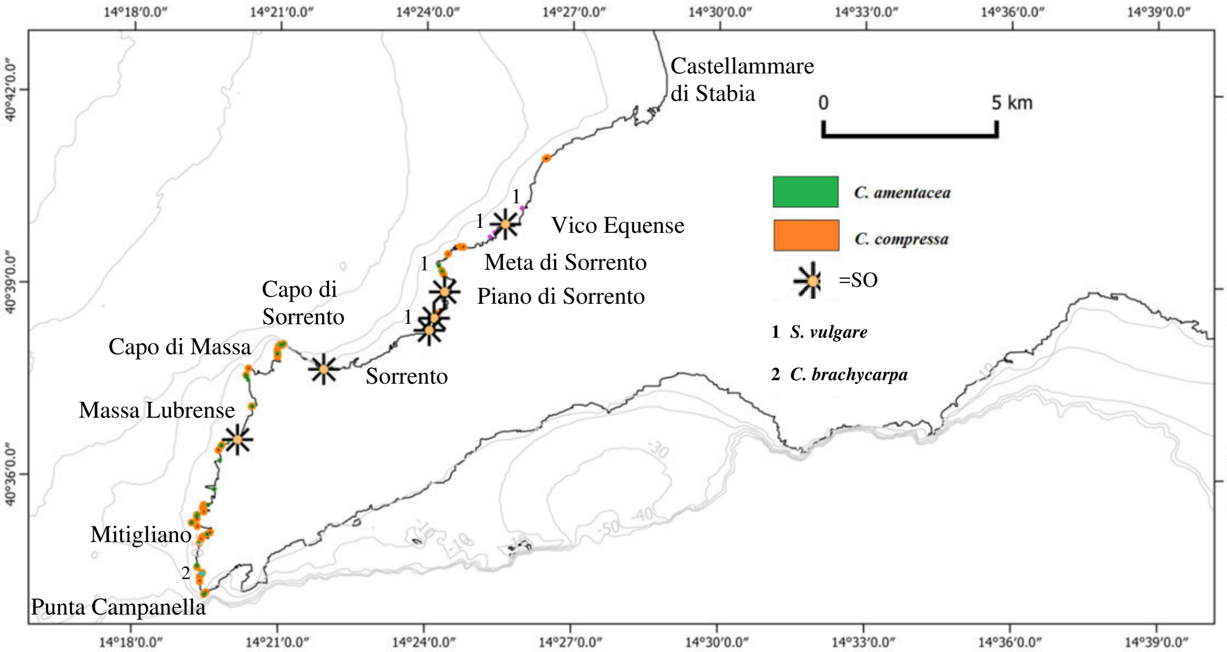


Figure 100: Fucales distribution in Sorrento Peninsula. SO=Sewage outfall

Sorrento peninsula had spots assemblages of shallow Fucales (Figure 98). This could be due to the high coastline and slope that are mainly present along the region. In total 4 shallow (CC, CA, CBR and SV) and 6 deep species (CBR, CF, CSA, CS, CZ and SA) were found. The shallow species were present with different abundances: *C. compressa* (the most abundant), *C. amentacea* (spots) and few sites with *S. vulgare* close to Vico Equense. There were also some *C. brachycarpa* specimens in few rock-pools at Fossa Papa. *Cystoseira foeniculacea* forma *foeniculacea* was found in a rock-pool of few square meters (40.6344 N; 14.3515 E) close to Bagni della Regina Giovanna. Detailed information for shallow species is available in the Annex II.

Regarding the deep species, CF (*Cystoseira foeniculacea* cfr. *latiramosa*) was found also in sublittoral habitats in Mitigliano Bay at 20 m.

During the surveys, I found also few patches of *Cystoseira zosteroides* at Vervece Bank (Figure 107), not previously reported. New findings were *C. sauvageauana* (Figure 106) in Cala di Mitigliano and *Sargassum acinarium* at Vervece (Table 14).

Sector E: Capri Island

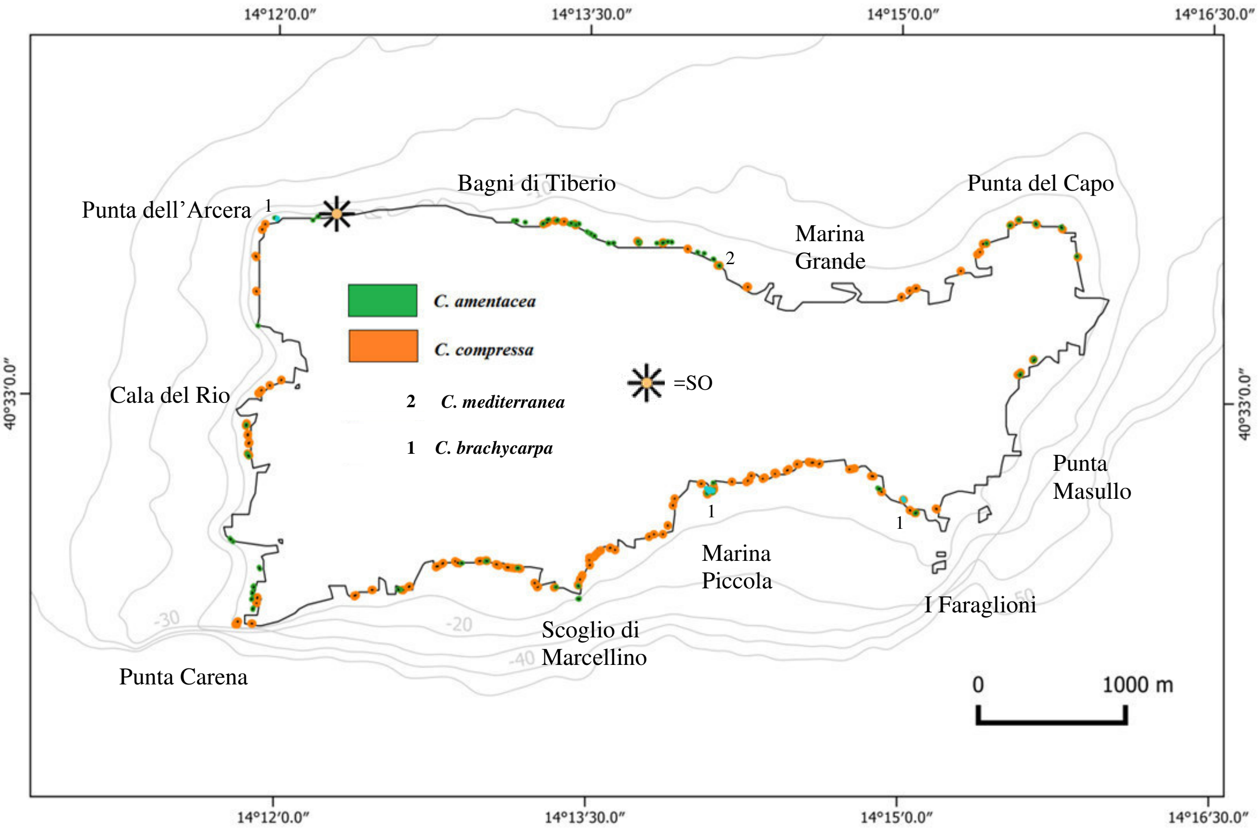


Figure 101: Fucales distribution around the Island of Capri (Sector E). SO=Sewage outfall

Along the coast of the island of Capri, 4 shallow (CA, CC, CBR and CMe) and 5 deep (CBR, CC, CF, CSA and CS) species were recorded. *Cystoseira amentacea* and *C. compressa* were widely distributed with fragmented populations. *Cystoseira brachycarpa* was spotted at low water mark in Punta dell'Arcera; it was found abundant at Scoglio delle Sirene (Figure 99).

The distribution in this area of the shallow species was probably related to the presence of high coast and no flat rocky zone (low slope) suitable for these species.

Some rock-pools were discovered, but the fucoids richness was less than those around Ischia (Sector A).

Regarding the deep species, we found *C. brachycarpa* (Bagni Tiberio), *C. compressa* var. *compressa* (Punta del Capo), *C. foeniculacea* f. *foeniculacea* (Punta del Capo, Scoglio della Ricotta), *C. sauvageauna* (Punta Carena) (Figure 100, 101, 103, 104 and 106).

Other deep species reported were the highly sensitive *Cystoseira spinosa* at Bagni Tiberio, Punta dell'Arcera and Scoglio della Ricotta; in this last site *C. spinosa* var. *spinosa* and *C. spinosa* var. *compressa* were both abundant (Table 14, Figure 104, 105).

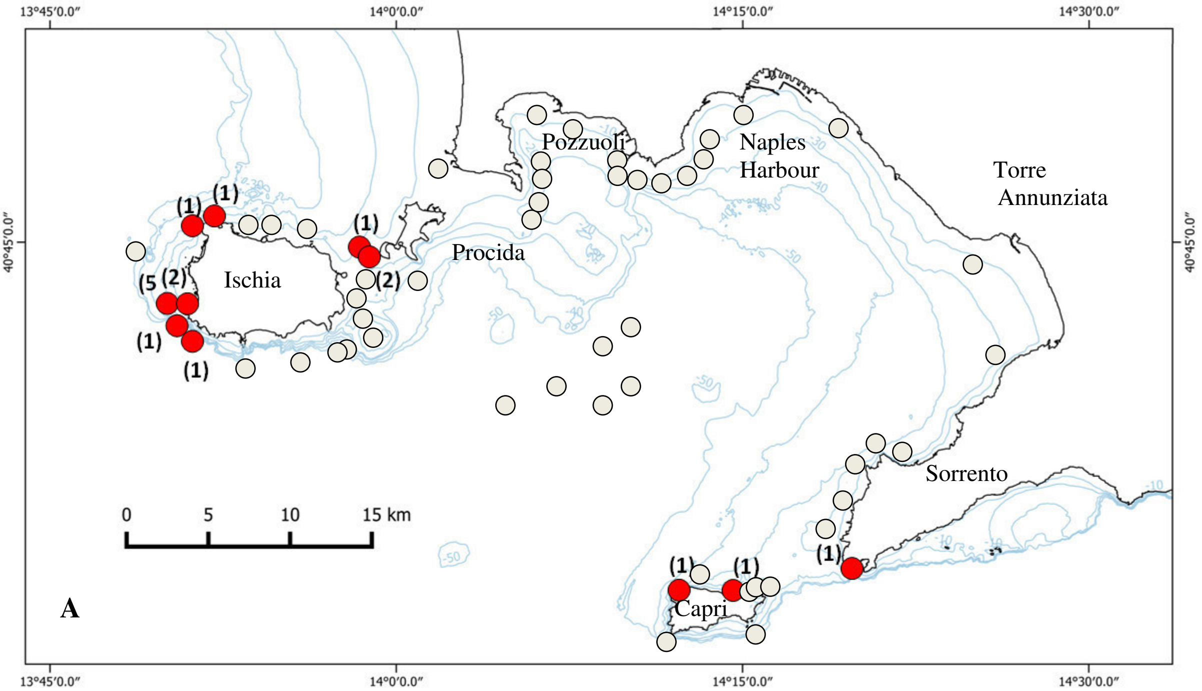


Figure 102: Occurrence of *C. brachycarpa* below the water mark in the study area (A) and *in situ* (B). Grey dots represent the absence of the species. Red dots represent the presence of the species. Numbers in brackets correspond to the semi-quantitative scale of abundance, from 1 (low) to 5 (high). For further information, see Table 14

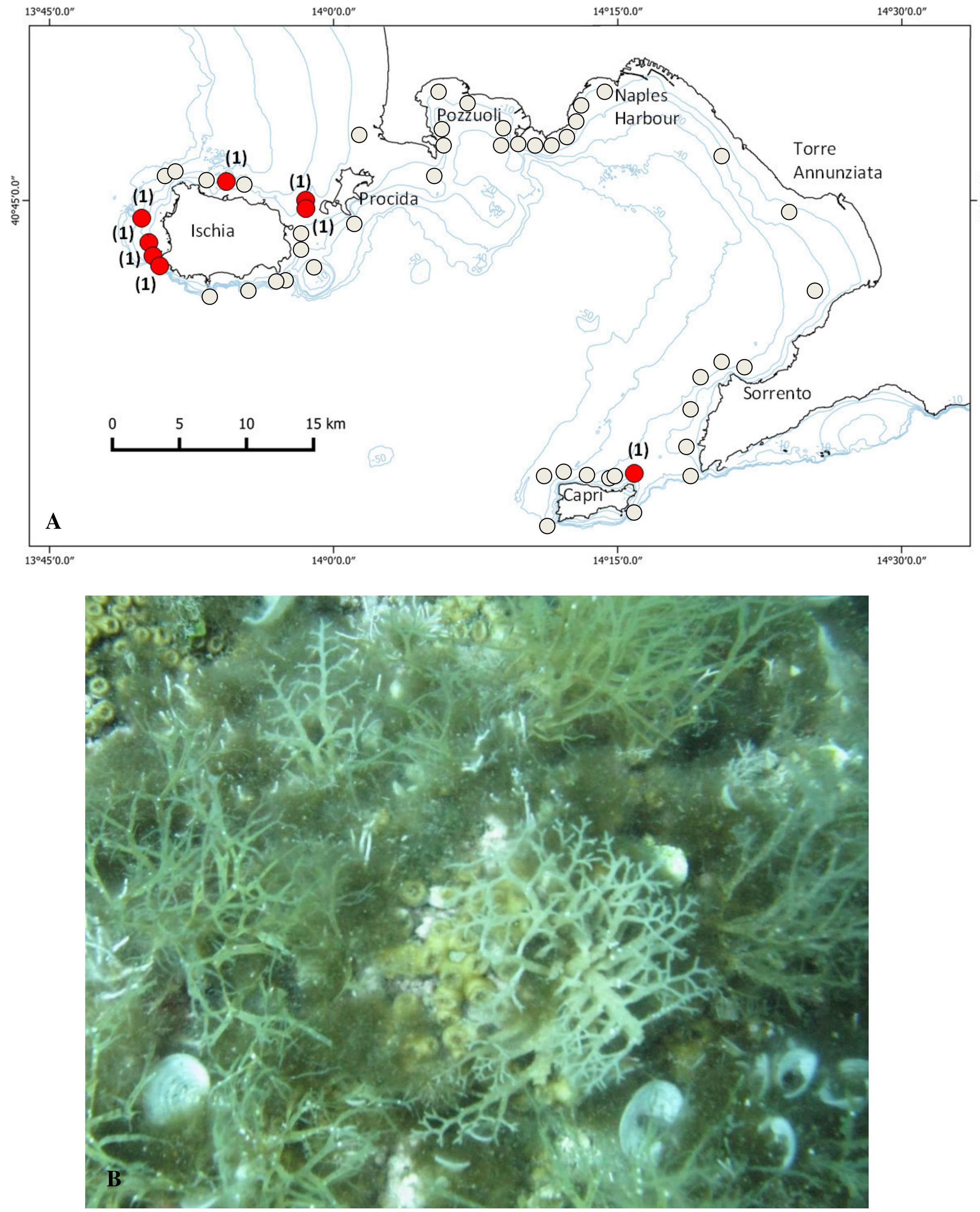
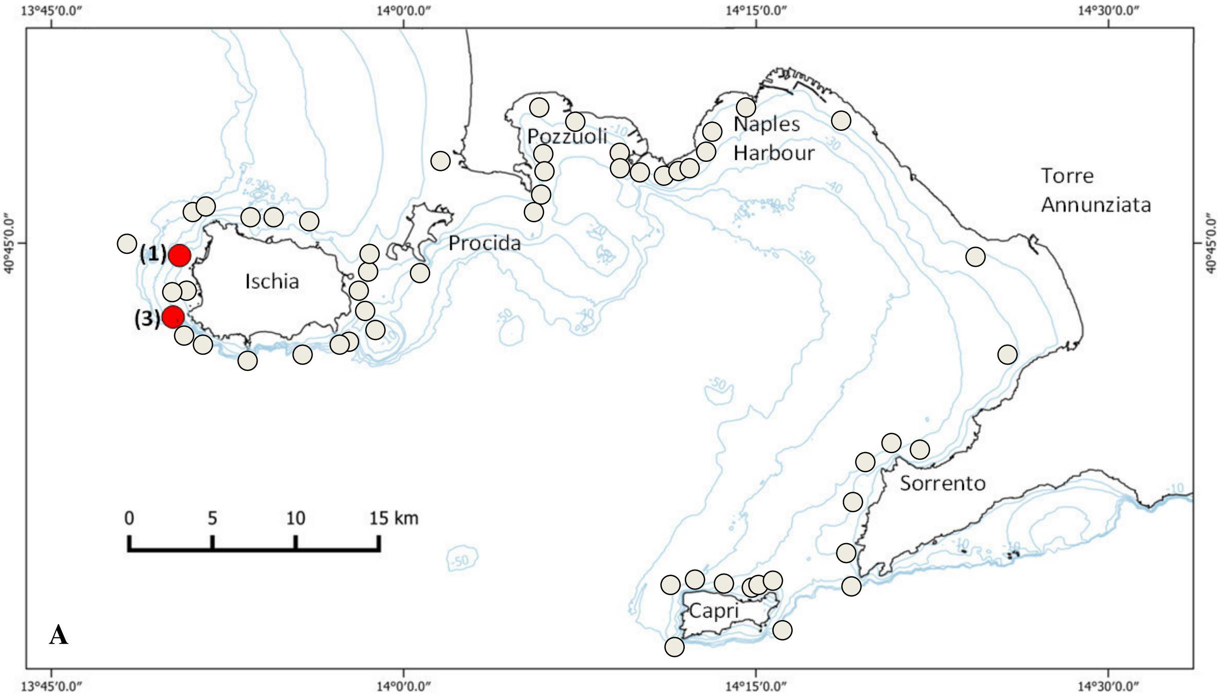


Figure 103: Occurrence of *C. compressa* var. *compressa* below the water mark in the study area (A) and *in situ* (B). Grey dots represent the absence of the species. Red dots represent the presence of the species. Numbers in brackets correspond to the semi-quantitative scale of abundance, from 1 (low) to 5 (high). For further information, see Table 14



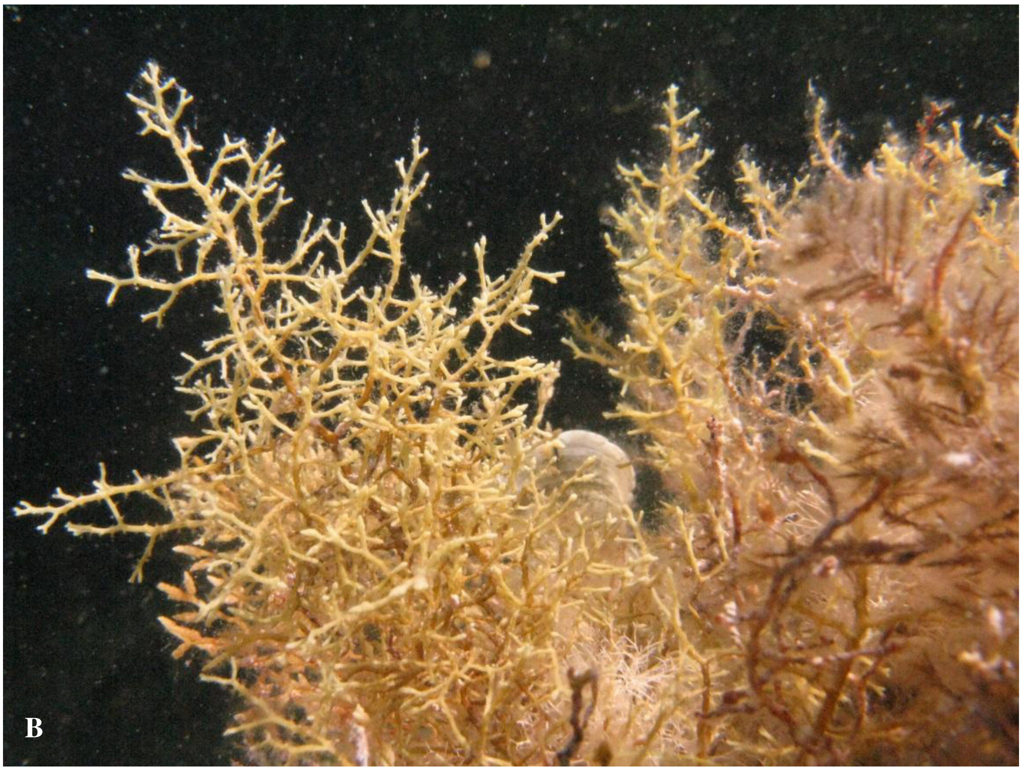


Figure 104: Occurrence of deep *C. compressa* var. *pustulata* below the water mark in the study area (A) and *in situ* (B). Grey dots represent the absence of the species. Red dots represent the presence of the species. Numbers in brackets correspond to the semi-quantitative scale of abundance, from 1 (low) to 5 (high). For further information, see Table 14

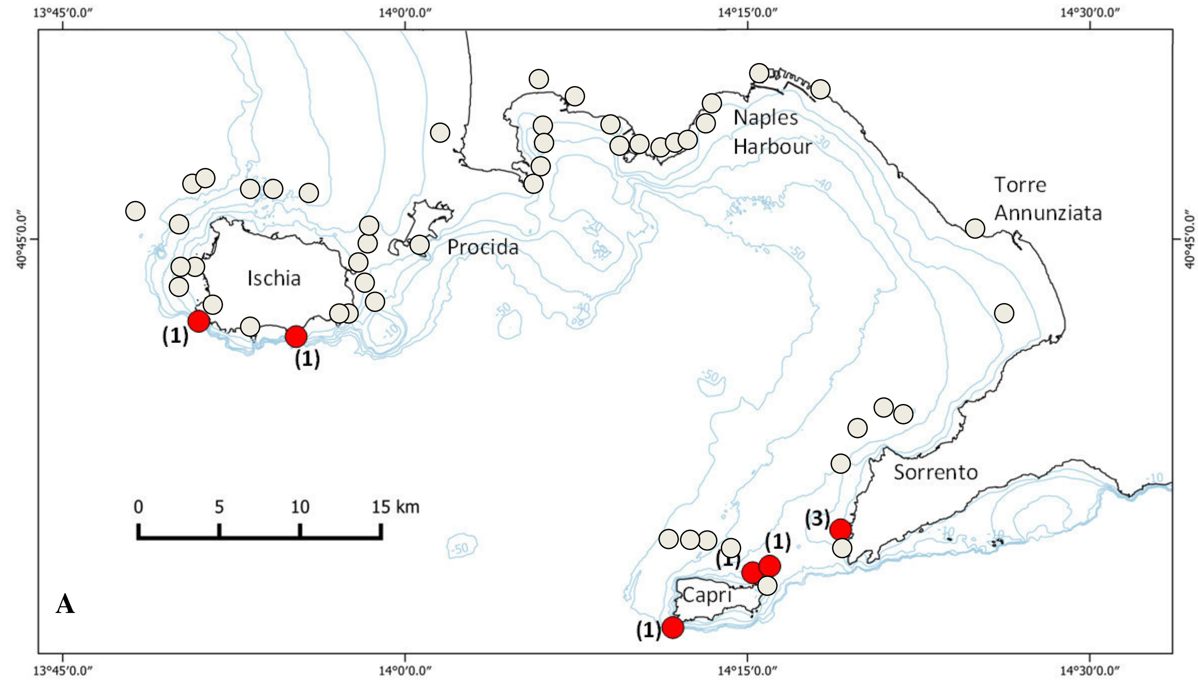


Figure 105: Occurrence of deep subtidal *C. foeniculacea* below the water mark in the study area (A) and *in situ* (B). Grey dots represent the absence of the species. Red dots represent the presence of the species. Numbers in brackets correspond to the semi-quantitative scale of abundance, from 1 (low) to 5 (high). For further information, see Table 14

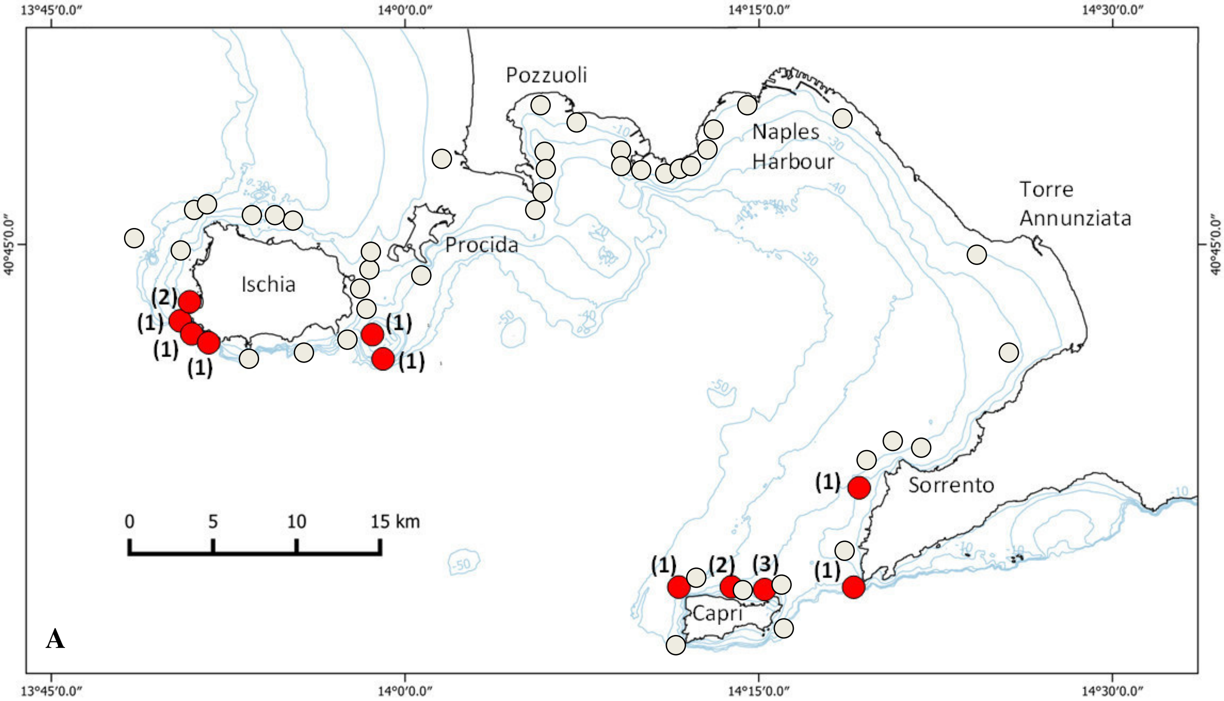


Figure 106: Occurrence of *C. spinosa* in the study area (A) and *in situ* (*C. spinosa* var. *spinosa*, B; *C. spinosa* var. *compressa*, C) below the water mark. Grey dots represent the absence of the species. Red dots represent the presence of the species. Numbers in brackets correspond to the semi-quantitative scale of abundance, from 1 (low) to 5 (high). For further information, see Table 14

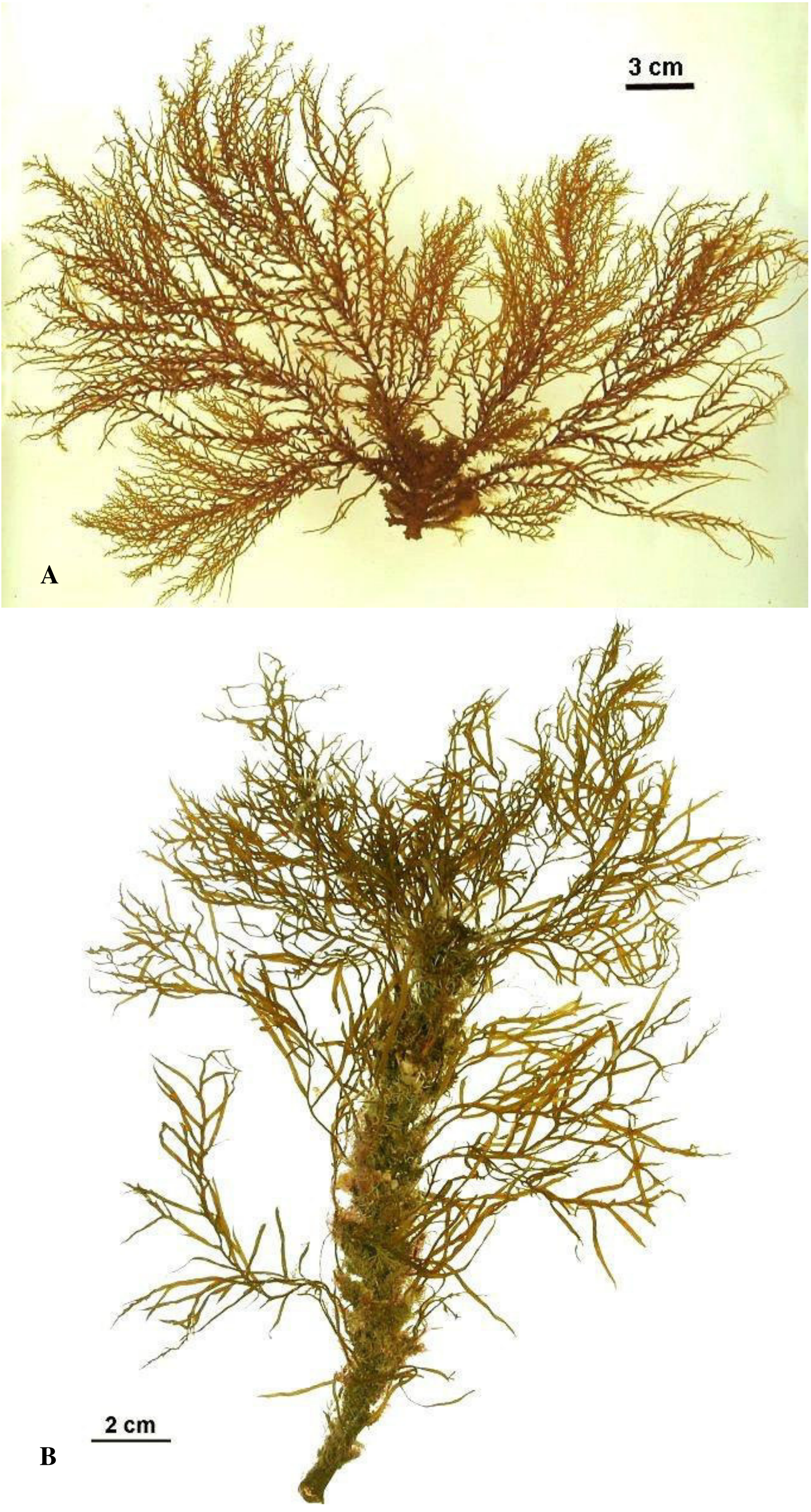
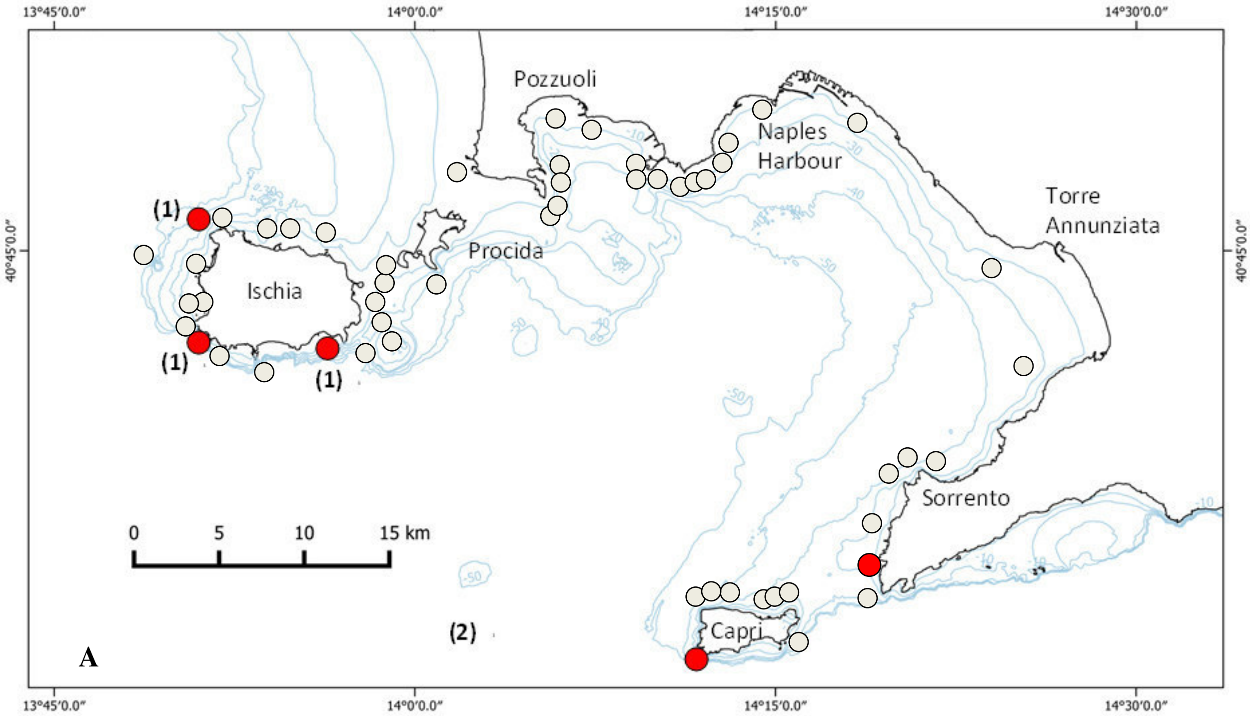


Figure 107: *C. spinosa* var. *spinosa* (A) and *C. spinosa* var. *compressa* (B) complete voucher herbaria (Photo Gianfranco Sartoni)



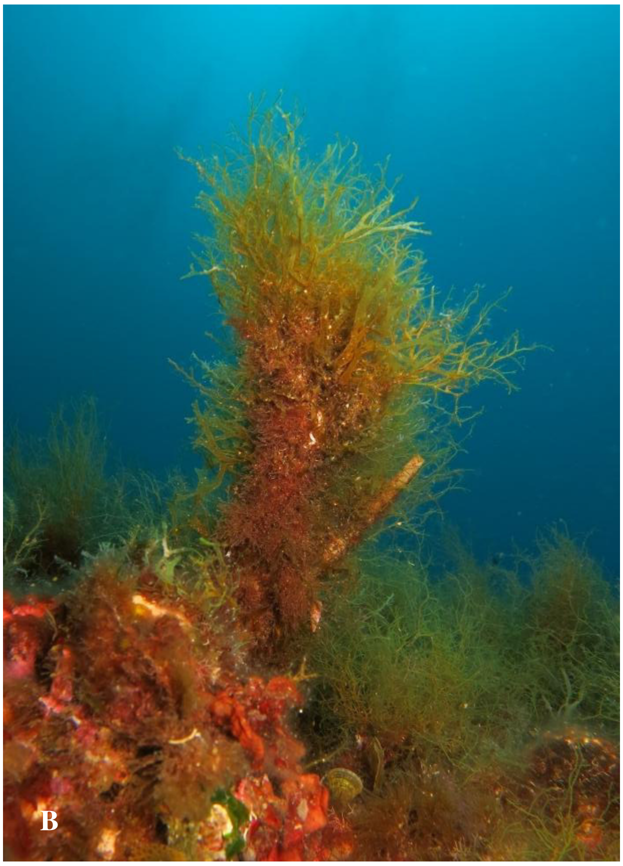


Figure 108: Occurrence of *C. sauvageauna* in the study area (A) and *in situ* (B). Numbers in brackets represent the semi-quantitative scale of abundance (1=low; 5=high). For further information, see Table 14

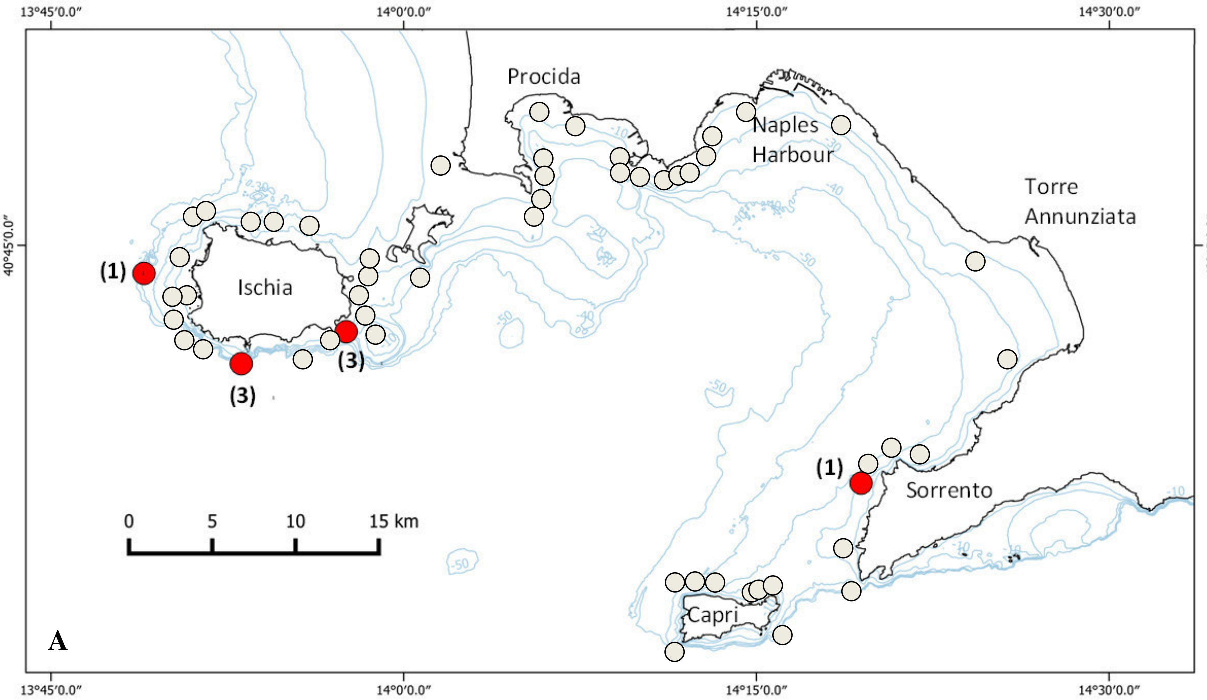


Figure 109: Occurrence of *C. zosteroides* below the water mark in the study area (A) and *in situ* (B). Grey dots represent the absence of the species. Red dots represent the presence of the species. Numbers in brackets correspond to the semi-quantitative scale of abundance, from 1 (low) to 5 (high). For further information, see Table 14

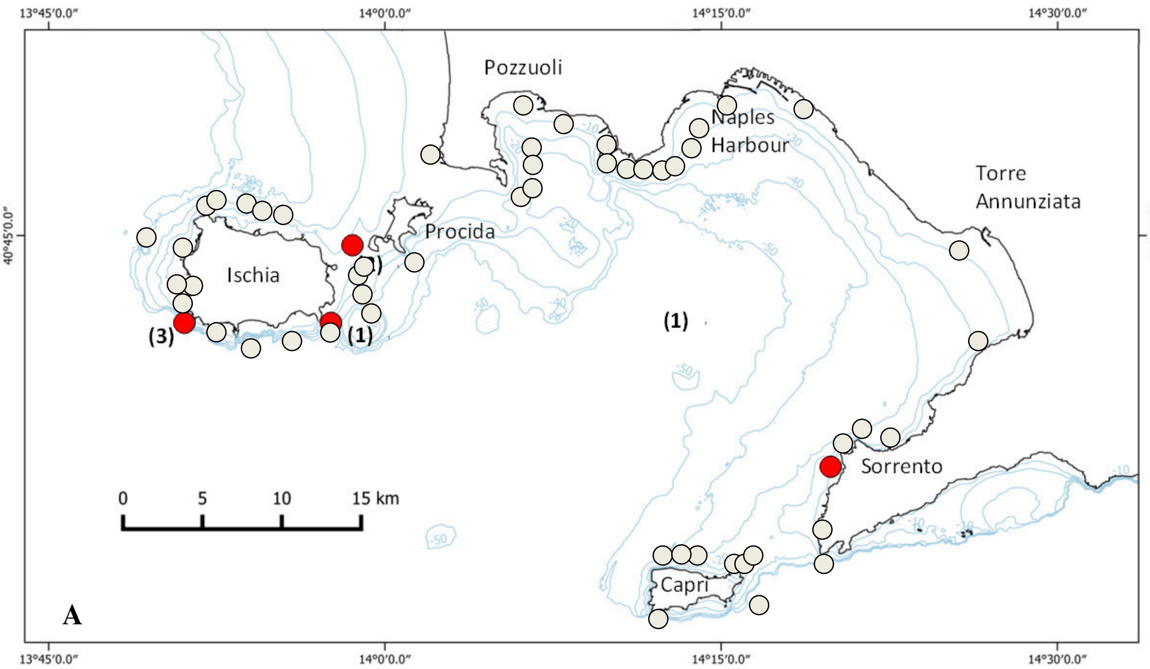


Figure 110: Occurrence of *S. acinarium* below the water mark in the study area (A) and *in situ* (B). Grey dots represent the absence of the species. Red dots represent the presence of the species. Numbers in brackets correspond to the semi-quantitative scale of abundance, from 1 (low) to 5 (high). For further information, see Table 14

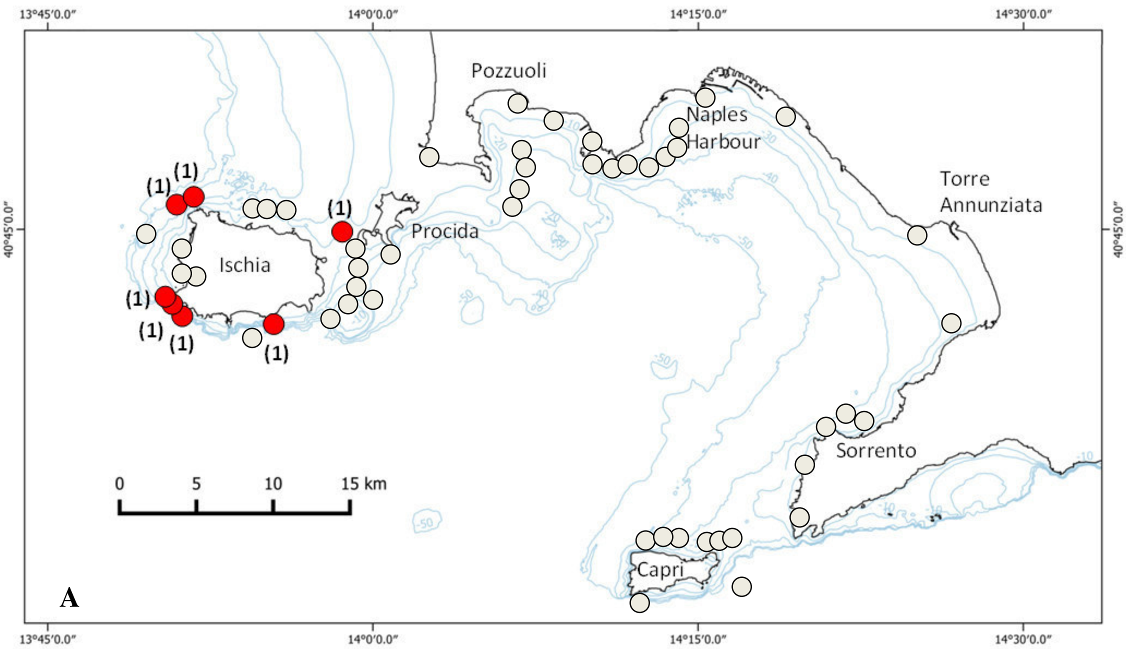


Figure 111: Occurrence of *S. vulgare* below the water mark in the study area (A) and *in situ* (B). Grey dots represent the absence of the species. Red dots represent the presence of the species. Numbers in brackets correspond to the semi-quantitative scale of abundance, from 1 (low) to 5 (high). For further information, see Table 14

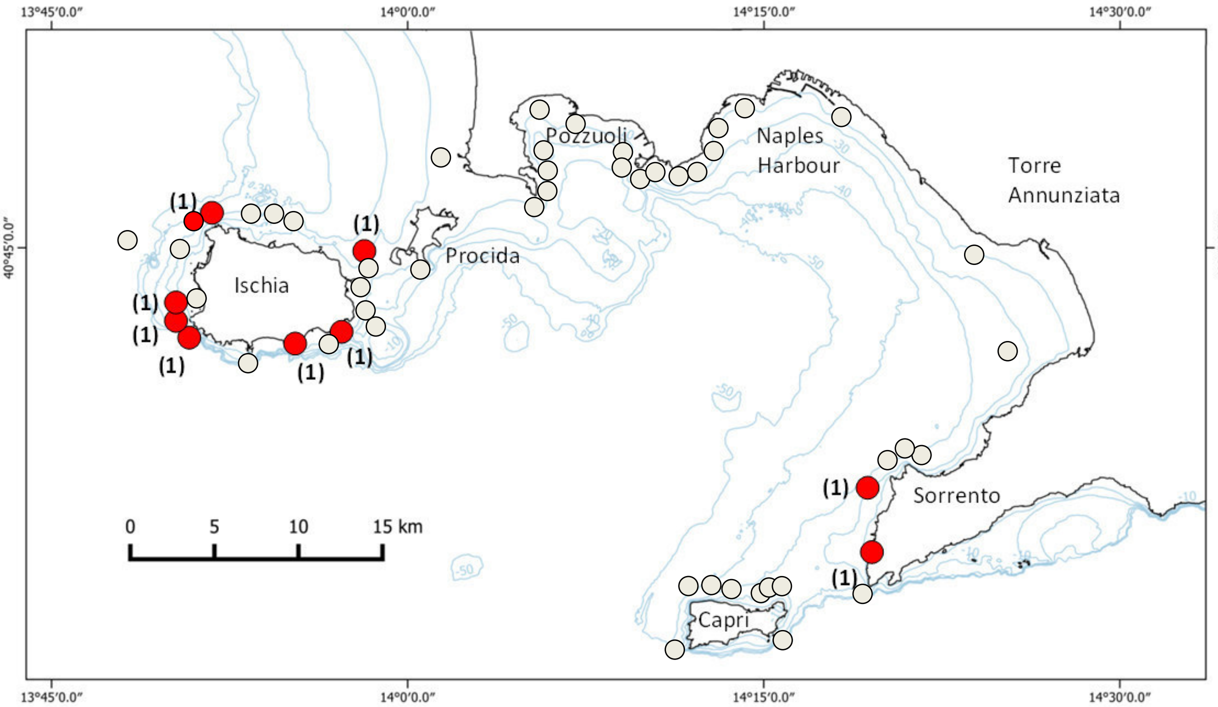


Figure 112: Current *Sargassum* sp. occurrence below the water mark in the study area. Grey dots represent the absence of the species. Red dots represent the presence of the species. Numbers in brackets correspond to the semi-quantitative scale of abundance, from 1 (low) to 5 (high). For further information, see Table 14

Table 14: List of sites below the water mark monitored in the 2013-2016 survey, divided by sectors. Classes of abundance of Fucales assemblages and of single species are reported (0=absent, 1=rare scattered individuals, 2=abundant scattered individuals, 3=abundant patches of dense stands, 4=scattered population, several patches covering several m^2, 5=dense populations). Relative Site Value (RSV) is derived by the product of the abundance of the Fucales and the abundance of each species (★= 1 and **★**=5)

Sector	Site	FUCALES abundance	Species abundance	Bathymetric interval	Relative Site Value (RSV)
A	Bell'Ommo	1	CBR(1), SV(1)	18-23m	★★
A	Capo Grosso	1	CF(1), SV(1)	25m	★★
A	Il Faraglione	2	CBR(2), SA(2)	18-24m	★★★★
A	Banco d'Ischia 1	0		30m	
A	Banco d'Ischia 2	1	CS(1)	48m	★
A	Secca di Forio	1	CZ(1)	50m	★
A	La Nave	1	CBR(1), SV(1), CCc(1)	10-15m	★★★
A	La Nave (east side)	1	CF(1), SV(1), CS(1), CBR(1), CC(1)	29m	**★**
A	La Nave (outer side)	1	CBR(1), SV(1), CS(1)	30m	★★★
A	Le Camerate	1	CCp(1), CCc(1)	1-9m	★★
A	Pietra Nera	5	CBR(5), CS(2)	5-14m	**★★**
A	Pietra Bianca	1	CBR(1), SV(1)	5m	★★
A	Punta Imperatore	3	CBR(1), SV(1), CS(1), CCp(3)	30m	**★★**★★
A	Punta Imperatore	2	CBR(2), CS(1), SV(1)	18- 25m	**★**★
A	Punta San Pancrazio	3	CS(1); CZ(3);SA(1)	30-34m	**★**★★★★
A	Punta Spaccarello	1	CBR(1), SV(1)	9-15m	★★
A	Sant' Angelo	3	CZ(3)	25-38m	★★★
A	Baia San Pancrazio	1	CSA(1)	10-31m	★
A	Scannella	2	CBR(1), SV(1), CSc(1)	5-20m	**★**★
A	Scannella	3	CBR(2), CSc(1), SA(3)	5- 27m	**★**★★★★
A	Secca del Santuario	1	CCc(1)	9m	★
A	Secca del Santuario 2 (Eliporto)	0		12m	
A	Secca Boa Gialla - Lacco Ameno	0		12m	

A	Secca delle Formiche	1	CCc(1)	13m	★
A	S. Anna	0		10m	
A	Punta Solchiaro, fino alla baia	0		0-35m	
A	Pisciazza	0		15m	
B	Capo Miseno	0		5-15m	
B	Grotta di Miseno	0		5-6m	
B	Baia	0		6m	
B	Pozzuoli	0		0-10 m	
B	Isolotto di S. Martino	0		0-10m	
B	Bacoli	0		0-25m	
B	Punta Pennata	0		10-20m	
C	Secca San Giovanni a T.	0		15-20m	
C	Secca T. Annunziata	0		35m	
C	Secca Badessa	0		1-25m	
C	Capo Posillipo	0		1-20m	
C	Posillipo	0		1-20m	
C	Rocce Verdi	0		1-20m	
C	Casa degli Spiriti	0		1-20m	
C	Nisida west side	0		1-20m	
C	Nisida East Side	0		1-20m	
C	Porto Paone	0		1-20m	
C	Santa Lucia	0		8m	
C	Secca di Nisida	0		20-25m	
C	Banco Santa Croce	0		9-40m	
D	Cala di Mitigliano	3	CBR (1), CFl(3), CSA(1)	19-25m	★★★★★
D	Punta Campanella	1	CS (1)	32m	★
D	Secca del Vervece	2	CZ(2)	38m	★★
D	Vervece Madonnina	1	CS(1), SA(1)	25-30m	★★
D	Punta del Capo-Puolo	0		28m	
D	Punta di Massa			20m	
D	Marina Grande			10-20m	
E	Caterola-P.ta del Fucile			13m	
E	Scoglio del Monacone			24m	

E	Grotta Azzurra W			38m	
E	Bagni Tiberio	2	CSc(2),CBR(1)	25-34m	★★★★
E	Punta Carena	2	CSA(2), CFf	28m	★★
E	Punta del Capo	2	CCp(2), CCc(1),CFf(1)	14-15m	★★
E	Punta dell'Arcera	1	CS(1)	20-24m	★
E	Scoglio della Ricotta	3	CS(3), CFf(1)	27m	★★

4.2.3 An overview of the temporal changes that occurred in the different sectors

The current number of all the species reported per each sector (from 0 to 50 m) is summarized in Table 15 and Figure 115.

The sectors with the highest biodiversity are those of Phlegrean Islands (A: 11 species in total; CCp, CCc, CBR, SV and CF occurred at both depth intervals), Sorrento peninsula (D: 9 species; CBR occurred at both depth intervals), and Capri (E: 7 species; CBR and CCc occurred at both depth intervals). An overall view of shallow and deep currents record of Fucales in the gulf are represented in Figure 113-114.

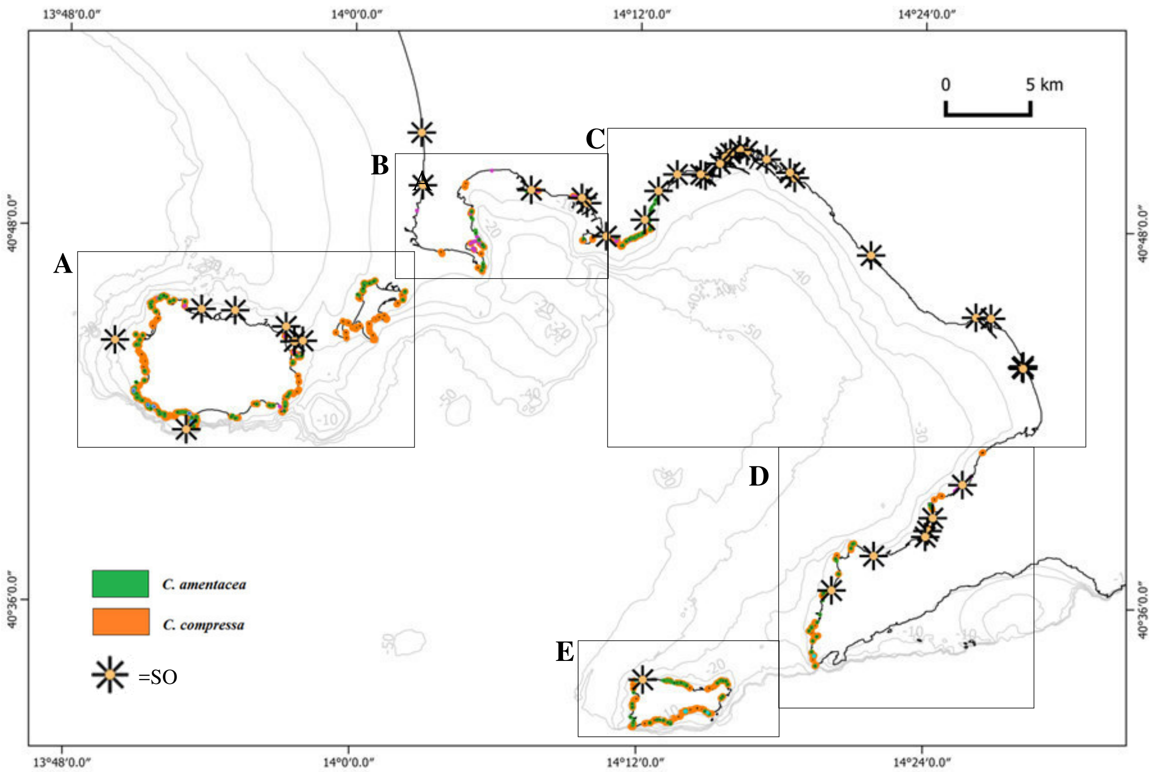


Figure 113: Overview of current distribution of shallow Fucales in the Gulf of Naples (only the most abundant species are evident in the map, represented in the legend). SO=Sewage outfall

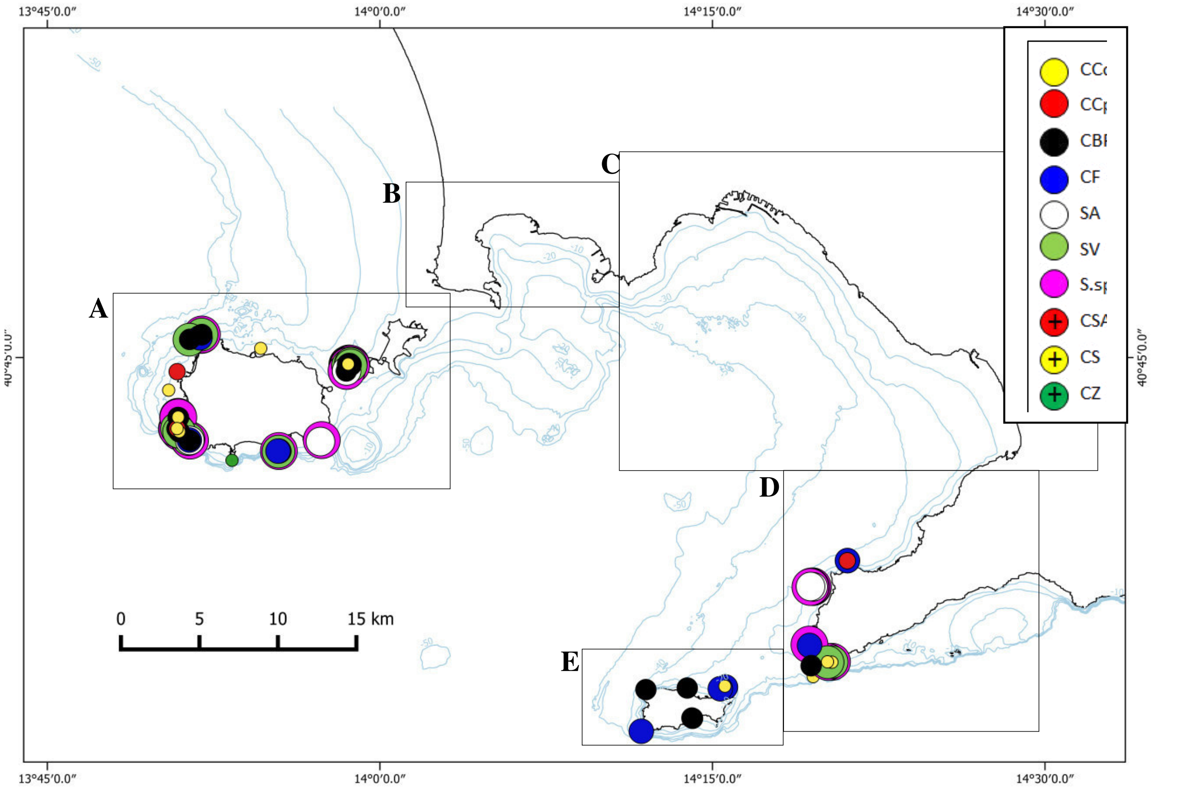


Figure 114: Overview of current distribution of deep Fucales in the Gulf of Naples (size of dots are different in order to avoid the overlay between species from the same site)

A comparison between current and historical fucoid occurrence has been done (Table 15) in which all the species found in the Gulf of Naples are reported.

A huge loss of biodiversity is reported in the gulf, in particular in the Sectors B and C (Figure 113 A, B). Most of the HR not recorded in the HR re-survey (Chapter 3), have been not recorded neither in the current survey (*C. barbata*, *C. barbatula, C. dubia*, *C. funkii*, *C. sedoides*, *C. tamariscifolia*, *S. hornschuchii*) in any sector.

Table 15: Summarizing table of the current (this Chapter) and historical (Chapter 3) distribution

	Current species				Historical Species	Change occurred	
	Shallow		Deep		(lost taxa in red)	Nr of lost Species	New records
Sector A		CA			CA		
					CB		
		CBR		CBR	CBR		
		CCc		CCp	CC		
					CD		
		CF		CF	CF		
		CMe			CMe		
	7	CRIN	8		CRIN	**4**	
				CSA			**CSA**
				CSs	CSs		
				CSc	CSc		
					CT		
				CZ	CZ		
				SA	SA		
					SH		
		SV		SV	SV		
Sector B		CA			CA		
					CB		
					CBR		
		CCc			CC		
					CD		
					CF		
		CMe			CMe		
					CSA		
	4		0		**CSc**	**11**	**SV**
					CSs		
					CSE		
					CT		
					CZ		
					SA		
					SH		
		SV					
Sector C		CA			CA		
					CB		
	3		0		**CBB**	**12**	
					CBR		
		CCc			CC		
					CD		
					CF		

	SV		**CMe** **CSA** **CSc** **CSs** **CT** **CZ** **SA** **SH** SV		
Sector D	4 CA CBR CCc SV	6 CBR CF CSA CS CZ SA	CA **CB** CBR CC CF **CFu** **CMe** **CRIN** CSs CSc CZ SA **SH**	**5**	**CSA**
Sector E	4 CA CCc CBR CMe	5 CCp CBR CF CSA CS	CA CC **CD** CF **CRIN** CSA CSs CSc **CZ** **SA** **SH**	**5**	**CBR** **CMe**

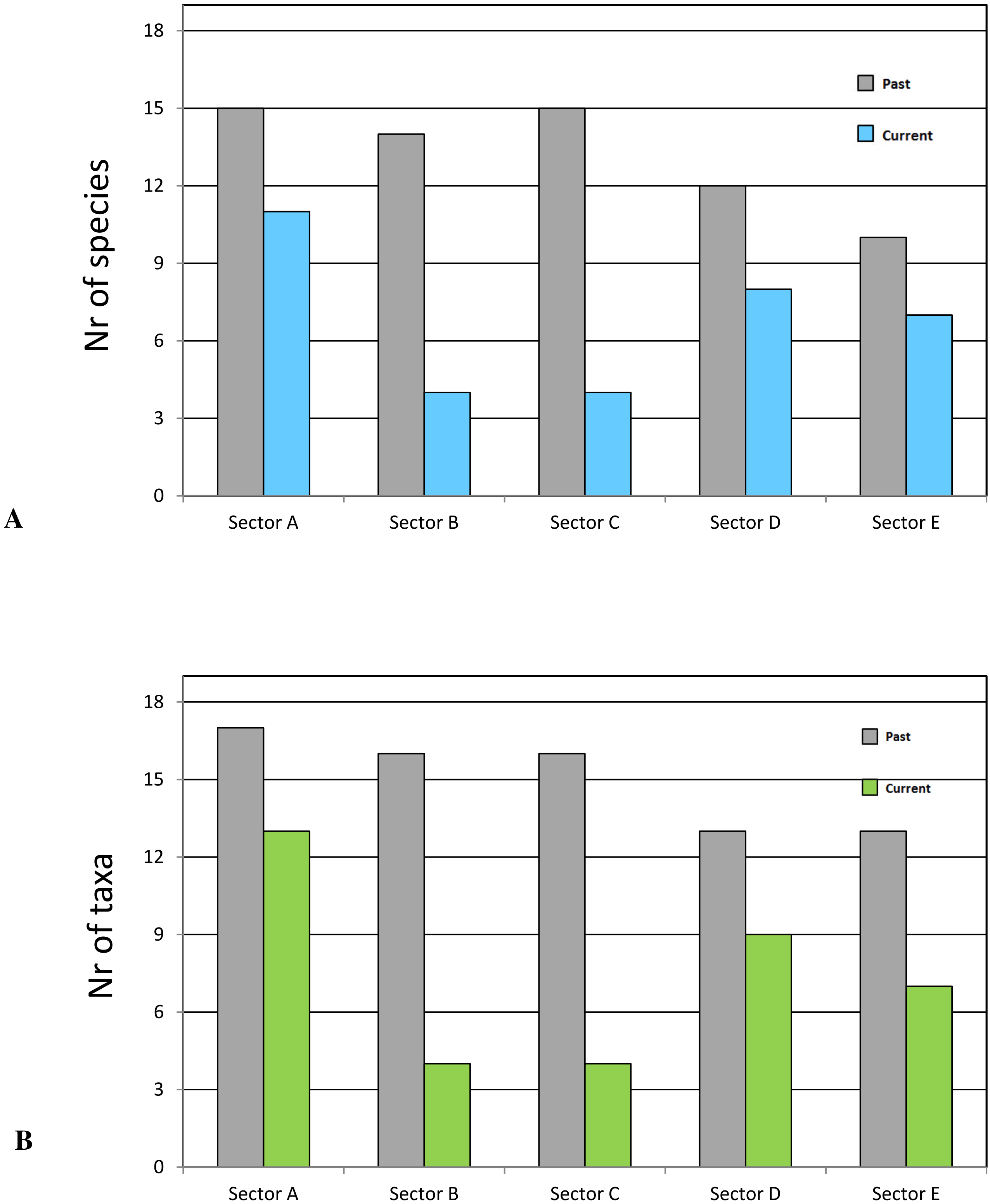


Figure 115: Historical and current number of species (A) and number of taxa (B) in the study area

4.4 Discussion

The Gulf of Naples has undergone to huge cumulative impacts from different human activities that are difficult to disentangle. These threats could be generally considered of lower magnitude far away from the coast. The results here obtained on the current richness and distribution of fucoid species seems to reflect the different human pressures exerted in the study area: in the Sector C (from Naples to Castellammare di Stabia) the highest number of lost species has been recorded. There are probably several reasons for the observed occurrence of Fucales and the eutrophication could be one of them, mainly affecting the shallow stands.

The eutrophication of the Gulf of Naples is extensively known but data are mainly related to Sectors B and C (Carrada et al., 1974; Ribera d'Alcalà et al., 1989); for the other sectors temporal changes in the dynamics of nutrients are few (Lorenti et al., 2005; Zupo & Buia, 2000). Moreover, many of the disappeared species are known to be species highly sensitive to nutrient enrichment, such as *C. mediterranea* (Ballesteros et al., 2007; Mangialajo et al. 2008, 2012).

An evident change in the coastal land use comes from the analysis of the artificialization of the coastline (Figure 116).

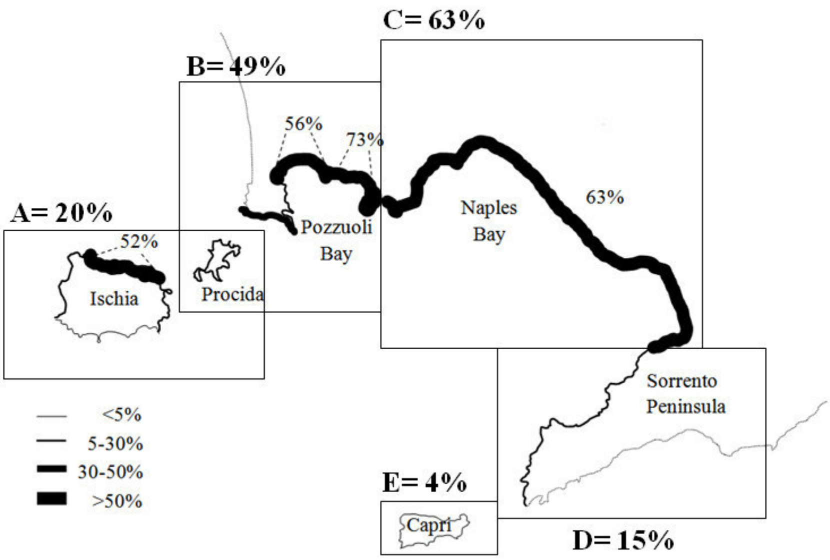


Figure 116: Artificial coast development for the different sectors (thick line) and sub-sectors (thin line) (from Grech et al., 2015b, modified)

Hard artificial structures have become ubiquitous features of coastal landscape as a response to the increasing human development in maritime areas and to prevent the coastal erosion (Chapman & Bulleri, 2003). In the Gulf of Naples the percentage of coastal transformation is a third of its coastline (34%), approaching very quickly to the 50% (Chapter 2). In general, the attention on the impacts that these artificial structures may have on the marine native ecosystems is currently very poor (Chapman & Bulleri, 2003; Airoldi et al., 2005; Bulleri & Chapman, 2010; Grech et al. 2015a).

Up to now, for the Gulf of Naples there are no quantitative data that correlate the changes in biodiversity of benthic organisms and habitats to this kind of coastal transformation.

The loss of species that I have recorded seems to be enhanced by the fragmentation of natural habitats. This loss probably may alter the connectivity among populations that in some case can result geographically far each other. A project to study the genetic distance between some fucoid populations at different spatial scale is ongoing at the lab of Ischia (Chiarore et al., 2015; Kumar, 2015).

Fishing pressure, marine traffic and anchoring could also play an important role in the reduction of fucoid richness. The first pressure could mainly produce mechanic damage on adult thalli while the second one, with an increase of sediment suspension and water movements, mainly close to entrance of harbours, could have a scouring effect on zygote settlement and juvenile stages (Vadas et al., 1990; Serrao et al., 1996; Schiel & Forster, 2006).

All the above activities are widely taken into account in the mediterranean depletion of Fucales by many authors (Munda, 1993; Airoldi &Beck, 2007; Mangialajo et al., 2008; Irving et al., 2009; Sales et al., 2011; Thibaut et al., 2005, 2015a,b).

The cause of loss per each sector is sometimes difficult to establish, because it is probably a synergic effect of multiple factors that resulted in this decline, but we can try to underline the main most probable drivers.

Sector A:

The Ischia Island currently hosts the highest biodiversity of the entire gulf (11 species and 14 taxa); in addition, CSA has never been reported until now in this sector. However, on its north side the seven shallow species CA, CC, CBR, CBA, CRIN, CMe, SA present in the past were not yet recorded. One explanation could be related to the highest percentage (52%) of coastal development on this side, with the constructions of harbours and marinas and depleting this area of suitable shallow rocky habitats for the settlement of fucoids. It is worth to note that on man-made structures here (composed by less complex substrates) no Fucales have been found.

The loss of algae along this side of the island could also be related (with additive or synergistic effect) to the outfall of the Volturno river (from the mainland) and to the several sewage outfalls without treatments on this side of the island, where the most crowded cities are settled.

The distance from the mainland (that is relatively low and the islands are easily reached by many people), the number of inhabitants and the coastal transformation seem the main factors driving this loss. A comparison with the Capraia Island (Tuscany, Tyrrhenian Sea, Italy) seems to confirm this hypothesis. This island in fact, has the same volcanic origin of Ischia, a similar coastal length and surface (respectively 27 km and of 34 Km^2) but it is farther from the mainland (55 km against 9 km of Ischia) and it is less permanently populated (400 inhabitants against 60,000). As a result, around the Capraia Island extended belts of *C. amentacea*, with very high mean coverage of *Cystoseira* spp. almost all along the coastline occur (PNAT, 2016; Benedetti–Cecchi et al. 2012; pers. obs.). Probably in Ischia the intense maritime commercial traffic contributed to negatively affect both the water transparency of the north side, especially in the touristic season, from April to October, close to main harbours (pers. obs.) and the scouring effect, with a dramatic effect especially on the early life-history stages of these species. Unfortunately, despite the existent literature of extra-Mediterranean brown algae (Vadas et al., 1990; Serrao et al., 1996; Schiel & Forster, 2006) little information on the impacts that these pressures may have on the recruitment of Mediterranean species are available (Irving et al., 2009). This interesting publication clearly showed that sediment strongly affects recruits, virtually precluding recruitment of *Cystoseira barbata* and greatly impacting the survival of recently settled germlings (up to 83% mortality). The result is quite surprising because *C. barbata* is a species that bears a certain degree of sediment load and it is more tolerant respect to other species. Since any natural or human induced restoration is highly dependent on the recruitment of early life stages, it would be interesting to test this approach to other more sensitive *Cystoseira* spp. The results should be useful for the interpretations of many cases of depletion reported in literature (Thibaut et al., 2005; Thibaut et al., 2015a,b; Blanfuné et al., 2016).

In the study site, the disappearance of *C. barbata,* a species as above mentioned with a higher level of plasticity respect to the high sensitive *C. amentacea*, could be related to the lack of suitable habitats (sheltered zones) and peaks or persistence of huge pollution events in the past that possibly depleted the species close to the water mark and/or extirpation due to fishing activities. *Cystoseira tamariscifolia* disappeared from Ischia since the end of XIX century and no clear explanations are available. As some other species, a possible incorrect taxonomic identification may occur, but also actual collapse is a possible occurrence.

Another relevant loss of richness has been found for deep species, probably more affected by the fishing pressure (that probably impacted from few to 70 m). This threat could be the cause of the loss especially for *Cystoseira dubia* and *Sargassum hornschuchii* and the depletion of other subtidal species. I have reported mainly isolated individuals of deep species and very few dense populations, such as the records of isolated specimens of the highly sensitive *Cystoseira spinosa* var. *spinosa* and *Cystoseira spinosa* var. *compressa* in the south west of Ischia. Most of the deep records I reported were never cited before but unfortunately few specimens were found. Most of the deep species can be probably considered relict specimens occurring in few sites (La Nave, Pietra Nera, Scannella, and Punta Imperatore). In addition, many fishermen told me that in the past (15-20 years ago) they found in their nets some algal species described as 'that bearing spiny balls' or that with 'the texture of a succulent plant' or 'the fragrant seaweed' that I easily identified respectively as *C. spinosa*, *C. zosteroides* and *Sargassum hornschuchii* showing them some pictures in the framework of the Citizen science project. They declared to fish these species quite occasionally but very deep (70 m) in a site of Ischia (La Secca, Banco d'Ischia).

Notwithstanding few trawling vessels are currently operating in the Sector A, the fishing fleet is the second biggest in the study area, after Sector C. Despite these data (Fleet Register, 2012), we have no idea about the pressure of the past activities and the relative impacts. The fishing fleet data evidenced a high number of gears that potentially can damage deep species. My personal observations of specimens entangled with long lines and fish nets confirmed this hypothesis (Figure 46 of Chapter 2, Figure 117). The fishing pressure around the Ischia Island

Figure 117: Recovery of an illegal fishing net in S. Angelo, Ischia (B.n.t. zone, Regno di Nettuno MPA) with *C. zosteroides* entangled (tophules on the right are evident)

has been semi-quantitatively evaluated in this thesis for the first time. The occurrence of the unique 'true forest' of *C. brachycarpa*, in an area where many emergent rocks surrounded the sandy bottom, seems to indirectly testify a lower role of artisanal fishery in that area.

The deep species are generally really sensitive to habitat alteration, with a K-reproductive strategy and low growth rate. In good environmental conditions, these algae form dense forests (Ballesteros et al., 1998) but they have reduced a lot their historical distribution from the past and several seem to be close to extinction. Management measures for these species should be taken into account for their conservation.

Sector B:

In the B sector, 14 species were present in the past but currently only 4 species (all shallow species) occur with a reduced distribution. This sector experienced an overall artificial coast development of 49%. In many cases, the habitat loss depleted the occurrence of shallow species and the current records of shallow species on artificial structures are very low, with patches of few dm^2 (generally very close to parental populations). In this sector, the so called Miseno Lake (that is actually a coastal lagoon) has been for many years a dump of domestic waste. Despite that, an attempt to a requalification of the area has started in the last 20 years: Bacoli area has been equipped with a sewage network system redirected to the treatment plant of Cuma, northward outside the gulf (Litorale Domizio). The output is composed by discontinuous treated waters (many different areas of the Campania plain) that are transported by southward currents close to the north coastline of Sector A and B (Casamicciola, Lacco Ameno, Ischia, Torregaveta, Procida, Monte di Procida). Currently the CA assemblages are locally dense and it is possible that after a past period of high disturbances (pollution, eutrophication) the shallow species are recovering (i.e. Bacoli, Capo Miseno). Considering the current status of sewage treatment plant, the occurrence and abundance is likely to increase in the future because of suitable habitat is available. The biggest disturbance that probably is currently acting negatively on Fucales assemblages is the harvesting of mussels and other animals; a widespread activity in the study area, commonly performed also in MPAs (especially B and C sectors; Figure 118).

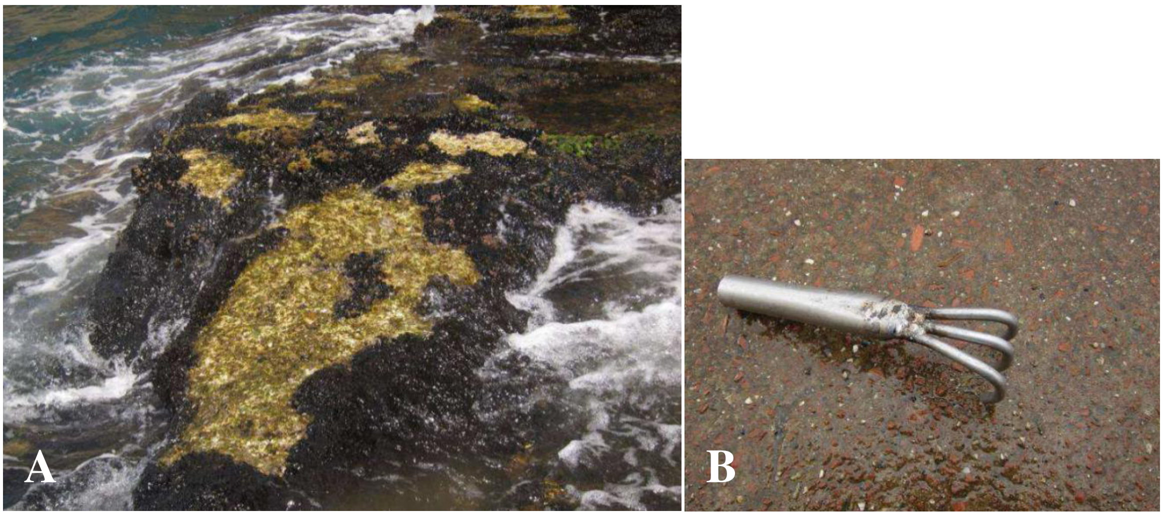


Figure 118: Effects of mussel harvesting (A) and artisanal device to scrape the rock, Gaiola MPA (Simeone et al., 2010)

The species below the water mark of this sector have totally collapsed (10 species completely lost; Table 14). The impact of fishing activities in this area is comparable to Ischia ones in term of number of vessels, but the categories of gill nets and long lines represent the most common fishing gear compared to those operating around the Phlegrean Islands (Sector A). This information probably contributed to a mechanical disturbance of the substrate year by year, resulting in the depletion of all the deep species and acting synergically with eutrophication, pollution and maritime traffics.

Mussel farming plants occurring in the area could have had a role in contributing to ensure a local oligotrophic coastal condition since they are placed close to Fucales belts (mainly dense populations of *C. amentacea*) and possibly they can filter many litres of water per day. Unfortunately no data on chemical and physical characteristics of the water masses are yet available for these populations. Anyway, this is an interesting hypothesis that could be taken into account and deserving to be tested in the future.

Finally, considering recreational traffic, Bacoli and Baia have the highest number of mooring places per harbour, being capable of receiving huge recreational boat traffic during spring and summer.

Sector C

After Romans that started to modify the environment with harbours and fishponds, this area experienced a high anthropogenic impact. An intense coastline change occurred, with the highest value of artificial development per sector: 63%. Here I recorded the highest loss of species: 11 Fucales species totally disappeared respect to the past records and moreover it was the sector with the highest reported past biodiversity in the study area (15 species and 16 taxa).

The sector experienced high eutrophication due to the extremely urbanized area outfalls in the period from 1950-1990 (Carrada et al., 1974, Ribera d'Alcalà et al., 1989). The toponymy referring to some sites is clear (i.e. "Rocce Verdi" in Posillipo coastline, means green rocks i.e. rocks covered by *Ulva* spp. and other *Chlorophyceae*, typical of eutrophic conditions or at least with a high rate of fresh water inputs). Sometimes it is almost impossible to believe that in S. Lucia (C sector) in the past, the high sensitive *C. spinosa* and *C. zosteroides* thrived here 'until 7-8 meters' (Valiante, 1883; Annex I). Today the water appears many times brown and dense communities of mussels and ephemeral algae cover the rocks. This area experienced an intense pollution input in the past. Local people remember that up to 20 years ago the water was commonly turbid in many sites. This turbidity close Posillipo probably has affected also the current vitality and settlement of *Posidonia oceanica* meadows, previously mapped by Parenzan (1956) but now replaced by dead matte (Simeone et al., 2016a,b).

A change in the trophic state of the coastal water, from bad to better conditions, could indirectly testified by decrease in nitrophilic algal species such as *Ulva* spp., data obtained by taking advantage of local ecological knowledge. Local people that I interviewed on the changes in the last 30 years complained about the loss of *Ulva* spp. as it is a desired ingredient for traditional Neapolitan dishes and now no more so conspicuous as in the past.

Currently, one of the most documented sources of sewage pollution inputs in the Posillipo coastline is the Coroglio outfall, as widely discussed in the Chapter 3. The area between Naples harbour-Torre Annunziata is interested by intense maritime traffic and by numerous discharges, added to the occurrence of the mouth of the Sarno River (one of the most polluted river of Europe). Here, articulated corallines, that generally extensively cover surrounding artificial structures, are replaced by a black carpet of mussels, with the highest density at S. Lucia, Naples harbour, Torre del Greco, Ercolano, Torre Annunziata, Castellammare. In this area a high concentration of outfalls was recorded (as represented in the map).

Another pressure that can have affected the settlement of fucoids in this area should be the fishery pressure, that here is huge. The highest number of trawling vessels of the entire study area is present here; gill nets are widespread and the occurrence of many ghost nets entangled to rocks has been documented during our surveys. We investigated the area with different techniques (scuba dives, ROV videos, technical diver videos) to detect the occurrence of deep species. However, no fucoids were recorded as well as other benthic organisms, such corals, in the past intensively harvested as reported by different authors (Mazzarelli & Mazzarelli, 1918; Bavestrello et al., 2014; Angiolillo et al., 2015).

Sector D

The sector D registered a loss of 5 species CB, CFu, CMe, CRIN, SH; on the contrary CSA, is a new finding. The artificial coastal development is low (15%) but the occurrence of shallow species is probably naturally hampered by the calcareous cliff of the Sorrento peninsula.

Also for this sector, untreated sewage outfalls are common, as evidenced in Chapter 2. Maritime traffic impact is very important and mainly related to touristic activities of Sorrento and other little harbours. Commercial fishing pressure is relatively low compared to other sectors and the effect seems to be evident in the high number of deep species (6). On the opposite, unfortunately, the harvesting of the date mussels, a forbidden activity, is still very common and causes severe damage to benthic communities.

Thanks to the Citizen Science Program, by analysing Ruspantini's pictures (a professional photographer) the occurrence of a deep population of *Sargassum* cfr. *acinarium* has been reported in Puolo.

Sector E

This sector has been poorly studied in the past; in addition more recent data (Ribera D'Alcalà & Russo, 2001) are referred to the occurrence of fucoids in general, without any taxonomic identification. As a consequence, results presented in this thesis are the first relevant baseline to detect any changes in their occurrence in the future. Seven specie have been currently recorded (CA, CMe, CC, CF, CBR, CSA, CS) and CMe and CBR were never recorded before. On the opposite, 5 species were not found again (CD, CRIN, CZ, SA, SH).

Artificial coast is almost nil (4%) and the unique known sewage outfall is located close to the Blue cave (Grotta Azzura) on the north side of the island. Maritime traffic is very high, especially during summer season, but the anchoring pressure (acting as mechanical disturbance) seems lower compared to other sectors due to high depths close to the coast. We may infer that low distance between isobaths and the oligotrophic conditions possibly guaranteed the conservation of both shallow and deep populations from high levels of disturbance. In addition, also fishing pressure can be considered very low: there are only two harbours and the fishing fleet is the smallest of the entire study area. Main gear is represented by long lines; all the other categories are scarcely represented and with the lowest number of involved vessels respect to the other sectors.

It is worth to note the occurrence of deep findings around the island of Capri. I found *C. sauvageauna* at Punta Carena (28 m); this species has been recorded by several authors in very shallow waters or a rock-pool, whilst in the gulf was historically mainly found in deep waters. Up to now, this record should represent the deepest finding of this species in the gulf and probably in the Mediterranean basin (Thibaut et al., 2015a). Another deep record is the most dense *Cystoseira spinosa* var. *compressa* population of the gulf, close to 'Scoglio della Ricotta' (at 27 m depth): the biggest assemblage of the entire study area.

4.5 Conclusion

The loss of historical species, the low abundance of existing species and the lack of deep subtidal forests in the Gulf of Naples seem to testify the missing of the structural and functional role (Thibaut et al., 2005, 2015; Gianni et al., 2013; Blanfuné et al., 2016) that these species could play along the coasts of the Gulf of Naples. The Neapolitan seascape experienced a shift to a less complex *Padina pavonica*, Dyctotales, *Stypocaulon scoparium*, *Laurencia* spp. and *Anadyomede stellata* assemblage with some ingression of non-indigenous species such as *Asparagopsis* spp. (Figure 119), *Caulerpa cylindracea* that has been observed especially both in shallow and deep habitats, in particular in the B, C, D sectors.

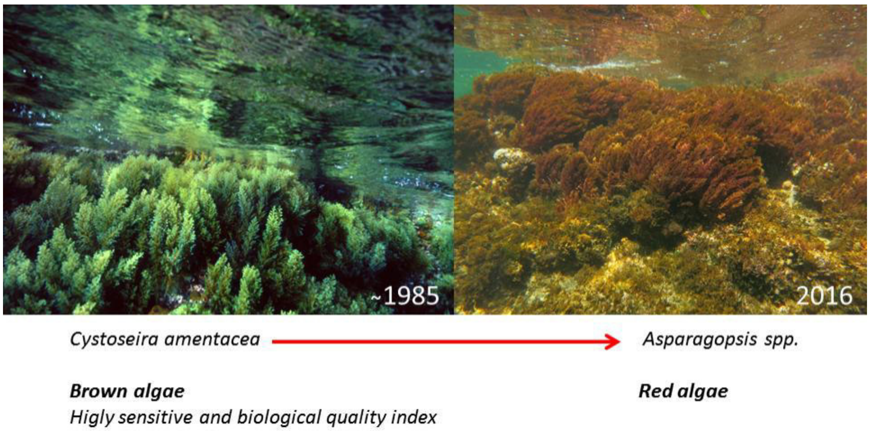


Figure 119: An example of the shift occurred in many shallow rocky habitats of the gulf (photo of 1985 is by Ernico Gargiulo)

The survey performed along the shallow subtidal fringes can be considered exhaustive and complete. On the other hand, the knowledge on deep populations cannot be considered completely exhaustive at all, since we didn't covered the entire seafloor surface of the gulf, but diving only in the sites considered the most suitable for the species. However, these suitable habitats for deep species have been generally found in limited areas, as evidenced by some authors (Hereu et al., 2008; Thibaut et al., 2015a) and personal observations. Adverse mete-marine conditions didn't allowed me to dive in all sites I had scheduled for my thesis and the quality of ROV videos in some sites was probably not very high to fill this gap. This is especially true for *Cystoseira dubia*, considering its size and further investigations are desired.

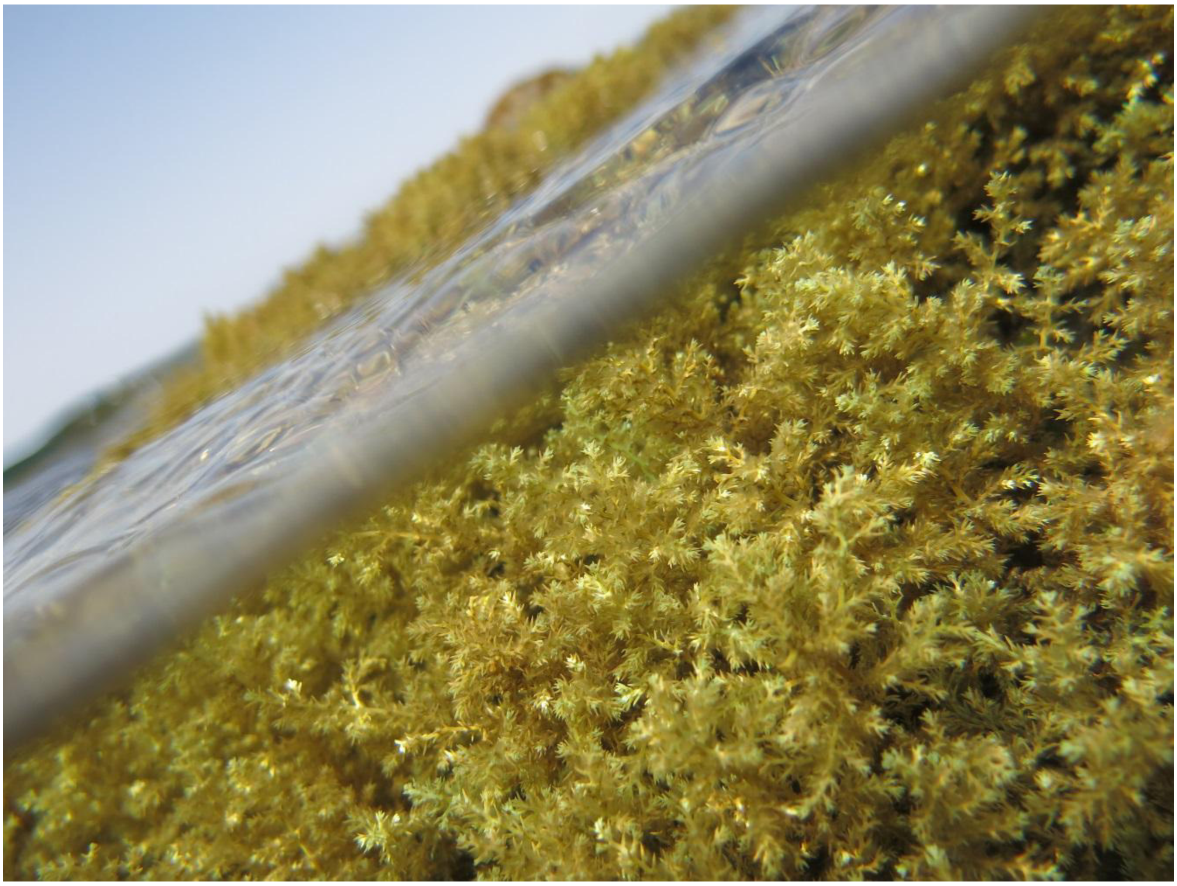
Moreover, there is a lack of historical density data as baseline for these species, because we are referring to species collected by the beginning of XX century, mainly through indirect collection methods (e.g. nets, dredges). This arise the question (really unlikely but theoretically possible) if the current status was the same of historical one. The comparison with the current status of other Mediterranean cases where Fucales commonly form dense forest (Spain, Italy, France) it gave important insights. Probably the reason why, also in an area with favourable conditions such as Ischia Island, these species are present only as rare and with scattered individuals is because they experienced since historical times huge human disturbance that lead to a huge depletion. Moreover the displacement of the food web through the overfishing of top predators could also have an important role in the disappearance of the species through the increase of grazers.

Recently Hereu et al. (2008) reported the occurrence of new previously unnoticed deep Fucales assemblages, in one of the best studied Mediterranean areas, the Port-Cros National Park (France). This site is clearly to be considered pristine respect to the Gulf of Naples and it is really unlikely that the same patterns could exist in the gulf.

In light of these data, the deep Fucales forest could be considered as good indicators of rocky seafloor disturbance, since they are capable of integrate through time the undergone pressure suffered along many decades, displaying the status of sea bottom by the absence or occurrence (and degree of occurrence) of their assemblages.

In conclusion, further monitoring activities (especially around Capri Island, understudied until now) have to be implemented to increase our knowledge of Fucales biodiversity and underwater seascapes, in order to calibrate future conservations efforts for these species.

5. A quantitative assessment of *Cystoseira* populations around the island of Ischia: a baseline to detect changes in their dynamics



5.1 Introduction

GIS mapping is a very useful and powerful tool to elaborate geographical data and detect the status and distribution of coastal benthic communities. When cartographic mapping is performed at a large spatial scale, is time and money consuming and it can be difficult repeat this effort at short temporal scales and limited resources. The best strategy to monitor the temporal dynamics of threated coastal systems, in particular those formed by habitat-forming species should be to select some sectors at different anthropogenic impacts, quantify the different parameters (plant richness, abundance, environmental factors) and follow them year by year.

Previous results (Chapters 2 and 3) highlighted historical changes of *Cystoseira* species and the huge pressures undergone the Gulf of Naples; for some sectors some stressors seemed to be the most relevant drivers of their regression. Around the island of Ischia, the most common and widespread species was the less sensitive *C. compressa* but no past or current temporal nutrient dynamics are known for the island.

One of the most important reported cause of loss triggering the decline of Fucales is eutrophication indeed (Thibaut et al. 2006, 2015a), but generally long and wide spatial and temporal datasets on nutrients are rarely available. The study area is not an exception, lacking of coastal detailed data of nutrients, especially for those sites that are hardly reachable for sampling, where there are currently concentrated the most dense Fucales assemblages. The unique long term available data are the Marechiara LTER water station of SZN but not reflecting the coastal waters patterns. It is of great interest so, to have a current status of Fucales assemblages coupled to nutrient analysis at least along some strength of coast for future assessment, being this type of analysis generally lacking for the island (Lorenti et al., 2005). Preliminary data of the current level nutrients of some sites of the gulf (Ischia, Procida and Pozzuoli) have been performed by Mulas (2013). Data referring to one day of sampling (punctual) with spatial replication seems to reveal that the values measured in the gulf are not so high to justify the absence of Fucales in the coastline and these data required further investigation.

In order to yearly monitor some sites characterized by a higher algal richness and extension, thanks to the results obtained from the Fucales mapping (Chapter 4) some different habitats of the island of Ischia have been selected to detect changes over time of different *Cystoseira* populations; they were localized in upper sublittoral belts, rock-pools and lower sublittoral stands. Four different coastal habitats with different type of Fucales assemblage and degree of impacts of the upper sublittoral habitat were investigated also through the inorganic nutrient analysis.

5.2 Material and Methods

Three different environments were selected: shallow belts (upper sublittoral belts), rock-pools and deep stands (lower sublittoral forest).

5.2.1 Upper sublittoral belts

The sampling effort was focused on 12 stations randomly chosen along the island of Ischia, excluding the north side (from Lacco Ameno to Punta Molino) and sandy shoreline where no Fucales currently occur (Figure 120; Table 16). In order to characterize nutrient pattern of the island, content in terms of NH_4, NO_2, NO_3, PO_4, SiO_2 were assessed in 4 sites with different degree of impact and Fucales assemblages. I monthly collected, from February 2016 to July 2016 (the period of peak of these species), 5 samples of water in 4 different sites. Three of these are coincident with 3 of the stations selected for the quantitative assessment (Rocce di S. Anna, ROS; Zaro, ZAR; Scannella, SCA) and one was located in front of Villa Dohrn, SZN (Punta S. Pietro, PSP). In this last station there are not currently reported Fucales assemblages, but *C. amentacea* (highly sensitive species) was historically present in the rocks in front of the SZN Lab (Historical Site; Buia pers. comm.).

Differences in nutrient concentration between sites (Si: fixed factor, with 4 levels: SCA, PSP, ROS, ZAR) and months (Mo: fixed factor nested in Si with 6 levels: Feb, Mar, Apr, May, Jun, Jul) were assessed by two-ways permutational multivariate analysis of variance (PERMANOVA) based on Euclidean distance (Anderson, 2001a, b). Data were fourth root transformed. A post-hoc pair-wise test was performed within the factor 'Site'. Significant differences observed in the PERMANOVA, were tested by similarity percentages (SIMPER) based on Euclidean distance in order to investigate the relative contribution of each nutrient to the evidenced differences.

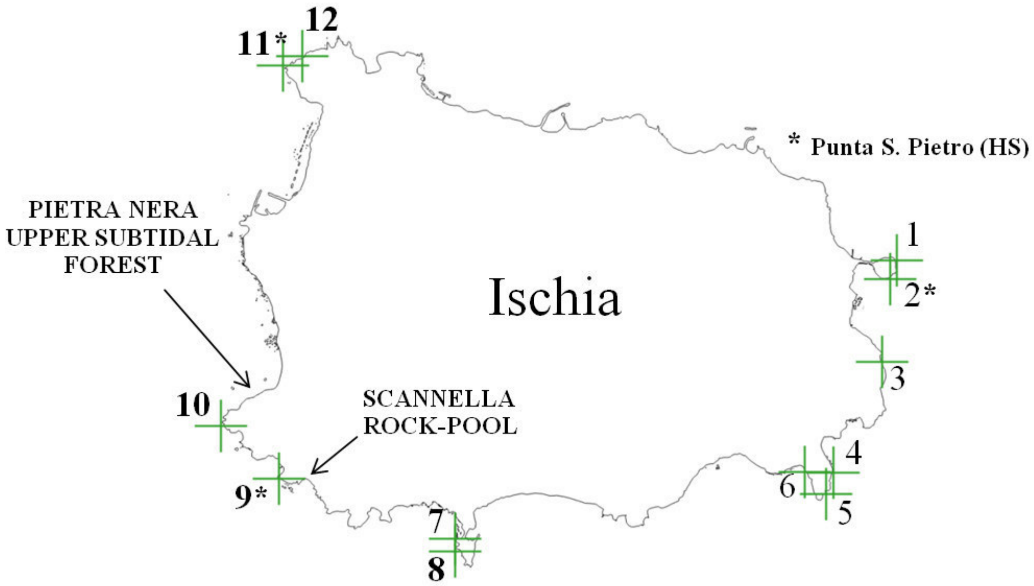


Figure 120: *Cystoseira* populations around Ischia selected for the quantitative assessment, * indicate the location where nutrient analysis was performed (for the code numbers, see Table 16)

These sites were geo-referenced and a visual census technique (VC) was applied to quantify and follow the dynamics of Cystoseira without damaging the local populations. For each of the 12 stations a sampling survey was done along three transects 20 m long and some

Table 16: List of stations around the island of Ischia with upper sublittoral belts of *Cystoseira* spp. monitored in 2014 (normal) and in 2016 (in bold the monitored transects also in 2016). * represent the stations where nutrient analysis was performed

Code	Sites	LAT N (DD)	LONG E (DD)
1	Castello NE	40.7322	13.9671
2	Castello E*	40.7298	13.9662
3	Pisciazza	40.7190	13.9642
4	P.S. Pancrazio S1	40.7036	13.9522
5	P.S. Pancrazio S1 bis	40.7016	13.9549
6	P.S. Pancrazio S2	40.7029	13.9558
7	**S. Angelo S1**	**40.6955**	**13.8918**
8	**S. Angelo S2**	**40.6944**	**13.8914**
9	**Scannella***	**40.7041**	**13.8610**
10	**Punta Imperatore**	**40.7109**	**13.8511**
11	**Zaro S1***	**40.7574**	**13.8618**
12	**Zaro S2**	**40.7586**	**13.8641**

environmental features were assessed. In particular the slope of the substrate and the Continuity of the *Cystoseira* spp. population were evaluated, this latter value representing the length expressed as percentage along the transect where we encountered the genus (without distinction of the species). At a smaller scale, for each transect, three quadrat (40 x 40 cm, Figure 121A) were used to evaluate the number of species, their coverage and the algal canopy, by measuring the length of the main axis in 3 random plants per quadrat (Figure 121B). The sampling transects performed between April and May 2015 were recorded by means of a GoPro Hero 3+ mounted by a head strap, as video evidence for future monitoring.

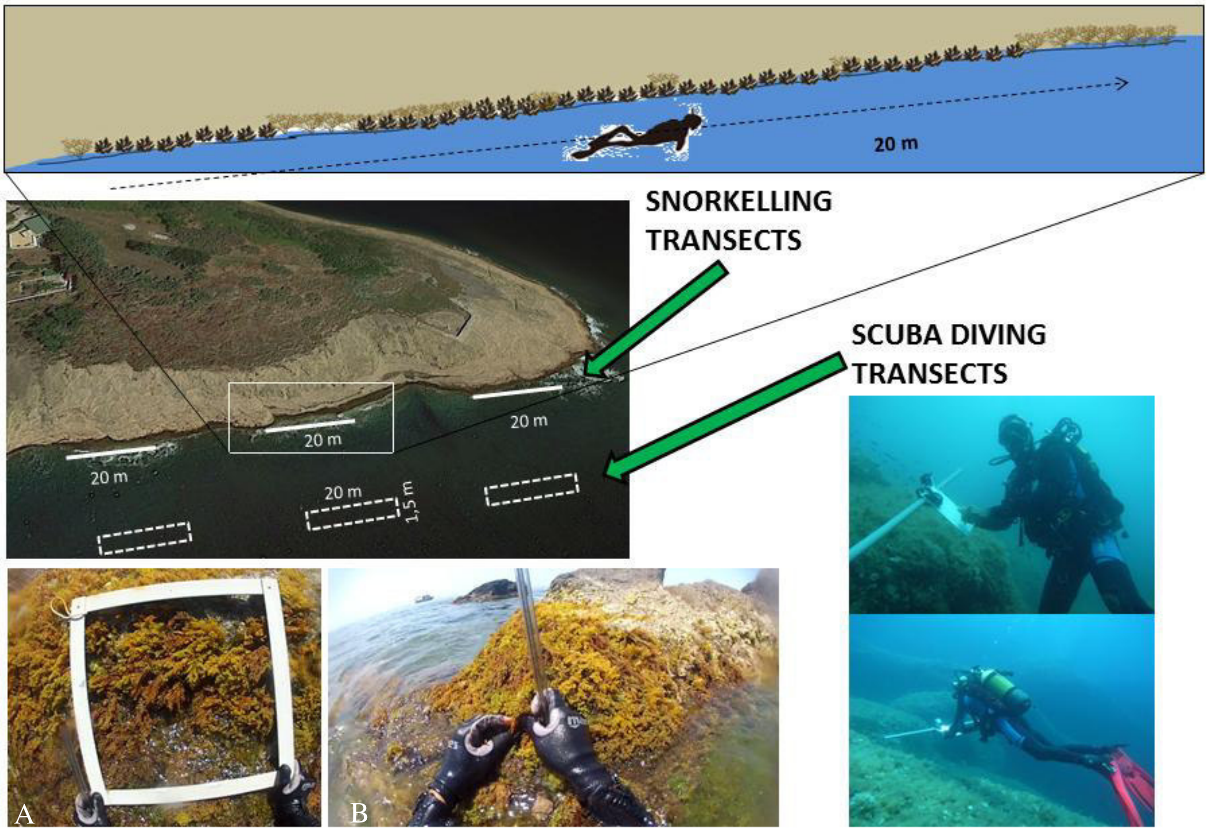


Figure 121: The Visual census (VC) methods performed in snorkelling for the 12 upper sublittoral belt stations and by SCUBA diving for the Pietra Nera lower subtidal forest

The latter parameter has been selected as it was easily measured in the water, and it can express the plant biomass (Ballesteros et al., 1998; Hereu et al., 2008).

Firsts measurements were performed in spring 2014 (12 stations). Two years later, in spring 2016, the monitoring program was repeated but limited to 6 stations only, due to the bad weather conditions (Table 12). The field procedures are represented in Figure 121B. The sampling transect was recorded by means of a GoPro Hero3+ that was mounted on an elastic head strap. The video records have been realized as evidence for future monitoring.

For the determination of nitrate, nitrite, ammonia, orthophosphates and silicates water samples (20 mL) where frozen at -20° C. The samples (N=5) were defrosted in a thermostatic bath at 37° C and the analyses were performed by the technicians of the SZN, using a continuous flow analyser (mod. Flow-Sys of Systea). The instrument is equipped with five continuous flux channels. Analyses were performed according to Saggiomo et al. (2010).

5.2.2 Rock-pool

Due to the geomorphology of the island, rock-pools are not common along the coasts; where the slope of the bottom less steep and some mass-rocks persist close to the surface it is possible to find some pools where several fucoids coexist. The biggest rock-pool of the island is found on the southwest side (Scannella; GPS coordinates: 40.703645° N; 13.861022°E) (Figure 96). It was mapped in 2015 during April (the period of maximum extension and growth of canopies) by means of 10x10 cm quadrat and orthogonal photo measures with ImageJ. The cover of each species was computed.

5.2.3 Lower sublittoral stands

The Pietra Nera site, on the southwest side of the island of Ischia, is the only true dense infralittoral forest up to now recorded in the Gulf of Naples (Figure 97). This site is a tuffaceous submerged shoal with an area of about 4,000 m^2 with an emerging rock of 100 m^2, less than 1km far from the Citara beach and located on a 20 m depth sandy bottom (where a *Posidonia oceanica* meadow is settled); from 0 to 15m depth the rock was covered by a very dense *C. brachycarpa* population. Between 10 and 14 m depth, some *C. spinosa* var. *spinosa* specimens are present, too. The density of this latter species was very low and spotted. We generally counted at least about 30 *C. spinosa* individuals per dive in the vicinity of transects, accounting for the whole site about 50 individuals distant each other from few decimetres to meters.

Three random VC transects 20 m long and 1.5 m wide were performed in a depth range between 8 and 12 meter (Figure 121).

Cystoseira spp. continuity was evaluated along each transect while to estimate the plant cover and dynamics, three random 20 x 20 cm quadrat per transect were used and phenological features such as coverage and canopy eight were measured. One sub-quadrat of 10 x10 cm per with *Cystoseira* spp. have been scraped per each quadrat to follow the phenology of the species. To obtain the dry weight, algal samples were put in the oven at 60°C until the constant weight was obtained (24 h).

5.3 Results

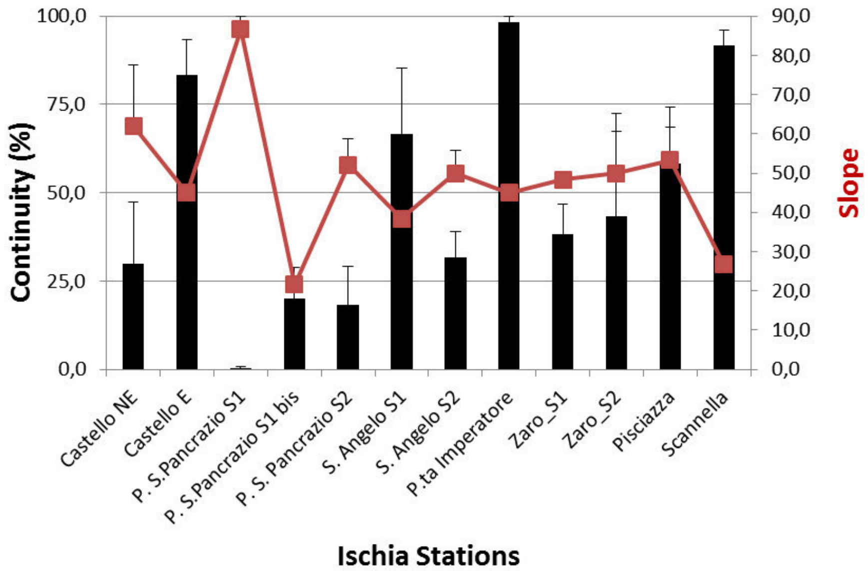
5.3.1 Upper sublittoral belts

C. compressa, *C. amentacea*, *C. mediterranea* and *C. crinita* characterized with different abundance the 12 sites around the island of Ischia (Table 17). *C. compressa* was the only species found to form monospecific dense belts and it occurred in all the sites.

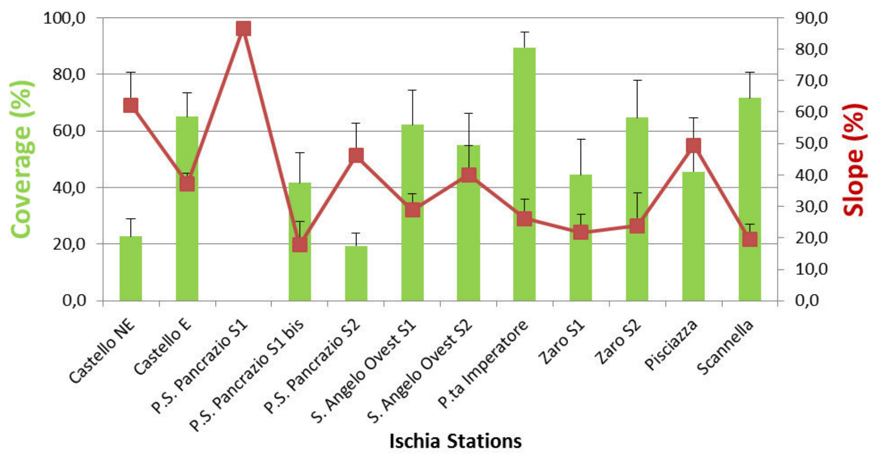
Table 17: Upper sublittoral sites selected in 2014. Stations are listed with the order of number of species detected (1, 2 or 3 species). In bold stations chosen for the two years later (2016) assessment. * indicates the stations for which temporal nutrient analysis has been performed

Code	Stations	Species recorded				Year of sampling
1	Castello NE	CC				2014
3	Pisciazza	CC				2014
4	P.S. Pancrazio S1	CC				2014
2	Castello E *	CC		CA		2014
11	Zaro S1 *	CC		CA		2014, 2016
12	Zaro S2	CC		CA		2014, 2016
5	P.S. Pancrazio S1 bis	CC	CMe			2014
6	P.S. Pancrazio S2	CC	CMe			2014
7	S. Angelo S1	CC	CMe			2014, 2016
8	S. Angelo S2	CC	CMe	CA		2014, 2016
9	Scannella *	CC	CMe	CA		2014, 2016
10	Punta Imperatore	CC		CA	CRIN	2014, 2016

The *Cystoseira* spp. continuity was not homogenous at all the localities and varied spatially, when it was present, from a minimum mean value of 1% at Punta San Pancrazio S1 to a maximum of about 98% at Punta Imperatore (Figure 122A). The coverage per each station varied between 0% at Punta S. Pancrazio S1 and 89.4% at Punta Imperatore (Figure 122B). The continuity of the belt seemed to be higher when the slope was low ($r = -0.58$; $p>0.001$) (Figure 123). There was a negative correlation also between number of species and slope of the coast ($r = -0.64$; $p<0.001$) (Figure 124) while a positive correlation between continuity and number of species ($r = 0.52$; $p< 0.01$) (Figure 125) was recorded; species richness was higher when slope was less steep.



A



B

Figure 122: Continuity (A) and Coverage (B) along the transects of *Cystoseira* spp. in the 12 sites around the Ischia Island (Mean±SE; nA=3; nB=9)

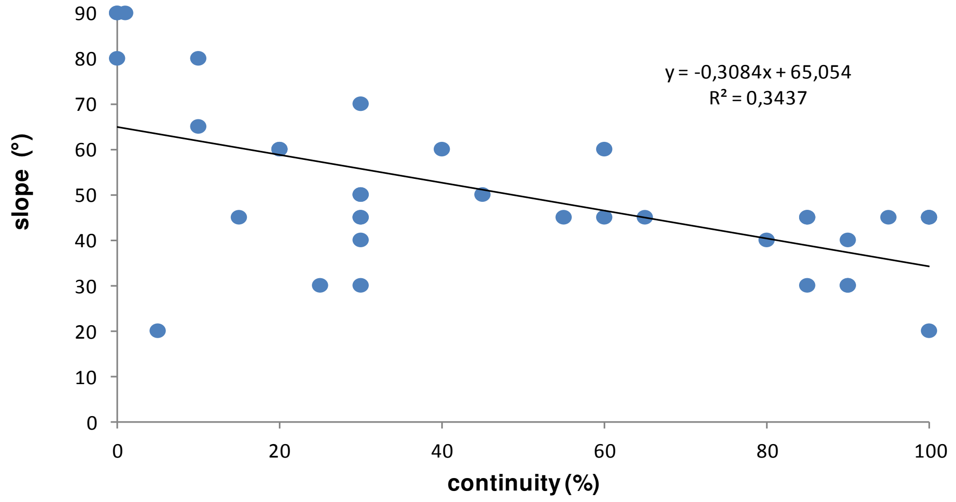


Figure 123: Correlation between continuity and slope along 12 stations (n=36)

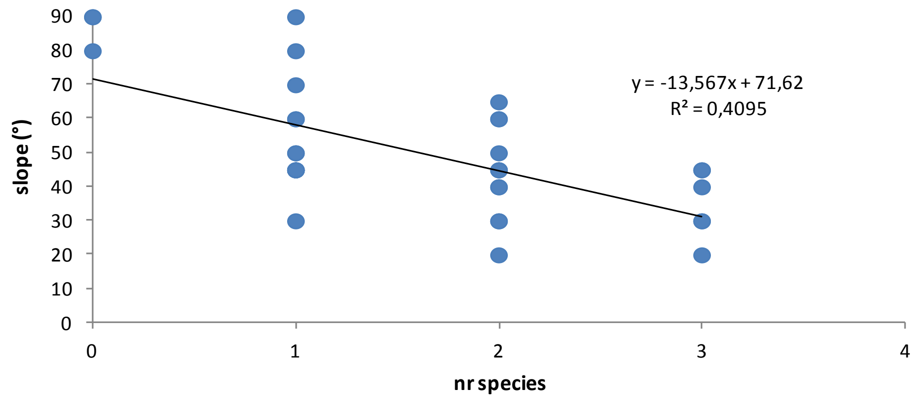


Figure 124: Correlation between coastal slope and number of species along 12 stations (n=36). Number of species: 1=CC; 2=CC, CA; 3=CC, CMe, CA or CRIN

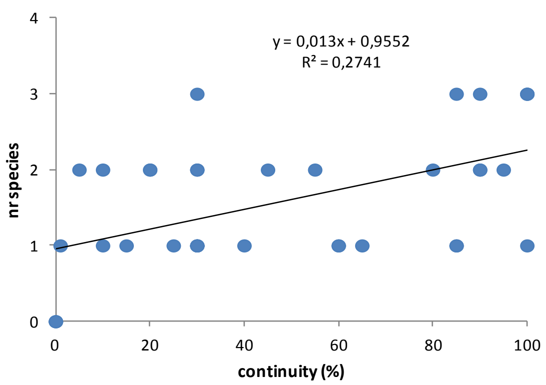


Figure 125: Correlation between continuity and number of species along 12 stations (n=36)

Considering only the stations respectively with mono-specific (CC), bi-specific (CC+CMe; or CC+CA) and tri-specific (CC+CMe+CA) populations (Table 17), the relationship between the coverage and the slope was negative (CC: $r = -0.67$; $p<0.001$; CC+CMe: $r = -0.43$; $p<0.05$; CC+CA: $r = -0.45$; $p<0.05$; CC+CMe+CA: $r = -0.45$; $p<0.05$).

Finally, considering all the species pooled together (*Cystoseira* spp.), the algal coverage was correlated to the slope of the coastline ($r = -0.59$; $p<0.05$; Figure 126).

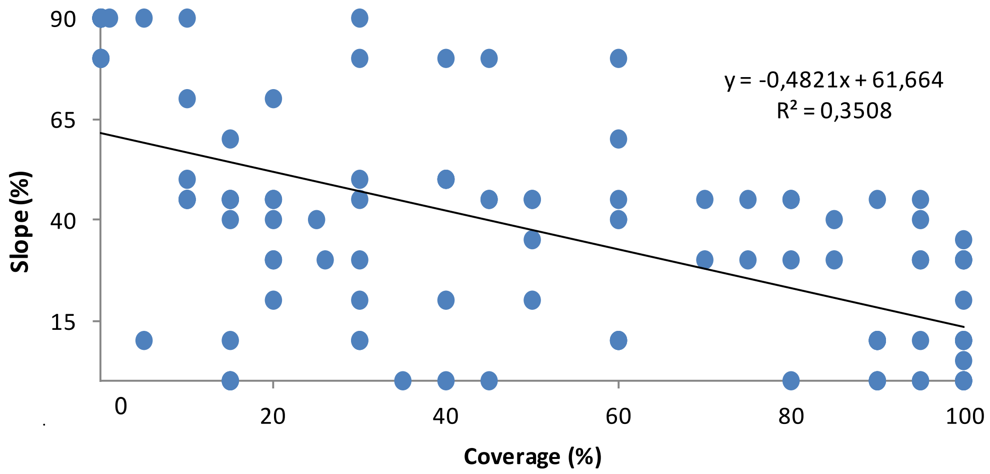


Figure 126: Correlation between the coverage and the slope of the substrate (n=108)

The variability of the length of the main axis of *C. compressa*, the most abundant species, at different spatial scales revealed that this species has highest values of canopy height in Castello E (12.5±1.0 cm) and Pisciazza (10.7±0.6 cm) as reported in Figure 127.

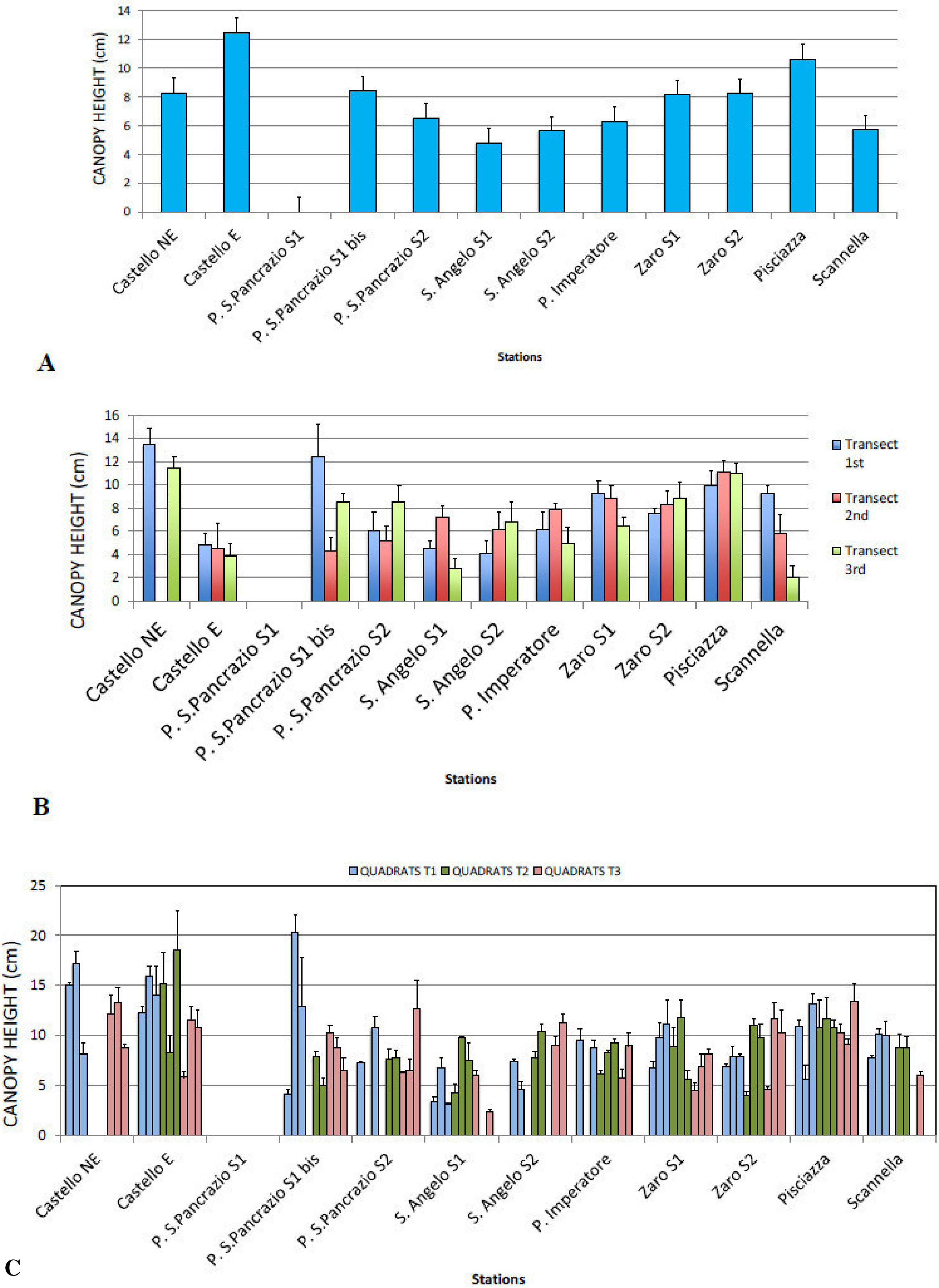


Figure 127: Variability of the length of the main axis (canopy height) of *C. compressa* among sites (A), transects (B) and quadrats (C) (mean ± SE.; nA=27, nB=9; nC=3)

Re-survey of 6 stations (S. Angelo S1; S. Angelo S2; Scannella; Punta Imperatore; Zaro S1; Zaro S2) were conducted during spring 2016 in the same period, to evaluate the first 2-years later trend. A simple t-test to assess if differences in the stations after two years have occurred, was performed and no temporal significant differences were detected either for the Continuity ($t=0.46$; $p>0.5$) and the Coverage ($t=0.46$; $p>0.5$).

The nutrient analysis performed in 2016, revealed a low content of nutrients in the 4 different sites with peak of nutrients in ROS and PSP during March, June and July (Figure 128,129; $p<0.01$, Table 18). Nitrates values were every time lower than 20 μmol/l (Figure 128), except for one station (ROS) in one month (March). PERMANOVA indeed, evidenced highly significant differences (Table 18).

Table 18: PERMANOVA nutrient results

Source	df	SS	MS	Pseudo-F	P(perm)	Unique perms
si	3	50.028	16.676	4.1014	**0.001**	999
mo(si)	20	154.64	7.7318	1.9016	**0.01**	999
Res	96	390.33	4.066			
Total	119	595				

Pair-wise test evidenced highly significant differences between the site ROS and SCA ($p=0.001$) and between the site ROS and ZAR ($p=0.002$) (Table 19).The similarity percentages (SIMPER) on the nutrient contribution for these differences revealed that nitrates (23.66%) and ammonia (20.65%) are responsible of 44.3% of differences between ROS and SCA (Table 20); silicates (27.65%) and nitrates (23.60%) are responsible of 51.2% of the differences between ROS and ZAR (Table 21).

Table 19: Pair-Wise test results for the factor Site (11=SCA, 12=PSP, 13=ZAR, 14=ROS)

PAIR-WISE TESTS

Term 'si'

Groups	t	P(perm)	Unique perms	P(MC)
SCA,PSP	1.494	0.098	998	0.127
SCA,ZAR	0.70751	0.564	998	0.566
SCA,ROS	3.488	0.001	998	**0.001**
PSP,ZAR	1.5008	0.1	999	0.122
PSP,ROS	1.2918	0.205	998	0.209
ZAR,ROS	3.6562	0.001	998	**0.002**

Table 20: SIMPER result for nutrients explaining the differences of the Pair Wise test between SCA and ROS

Variable	Group SCA Av.Value	Group ROS Av.Value	Av.Sq.Dist	Sq.Dist/SD	Contrib%	Cum.%
NO3	**-0.447**	**0.876**	**2.89**	**1.12**	**23.66**	**23.66**
NH4	**-0.383**	**0.336**	**2.52**	**0.62**	**20.65**	**44.31**
PO4	-0.544	0.516	2.32	0.58	19.03	63.34
SiO2	-0.386	0.742	2.24	0.82	18.37	81.71
NO2	-0.546	0.527	2.23	0.79	18.29	100.00

Table 21: SIMPER result for nutrients explaining the differences of the Pair Wise test between ZAR and ROS

Variable	Group ZAR Av.Value	Group ROS Av.Value	Av.Sq.Dist	Sq.Dist/SD	Contrib%	Cum.%
SiO2	**-0.687**	**0.742**	**3.01**	**0.97**	**27.65**	**27.65**
NO3	**-0.385**	**0.876**	**2.57**	**1.04**	**23.60**	**51.24**
NO2	-0.4	0.527	2	0.73	18.34	69.58
PO4	-0.433	0.516	1.78	0.56	16.38	85.96
NH4	-7.5E-2	0.336	1.53	0.60	14.04	100.00

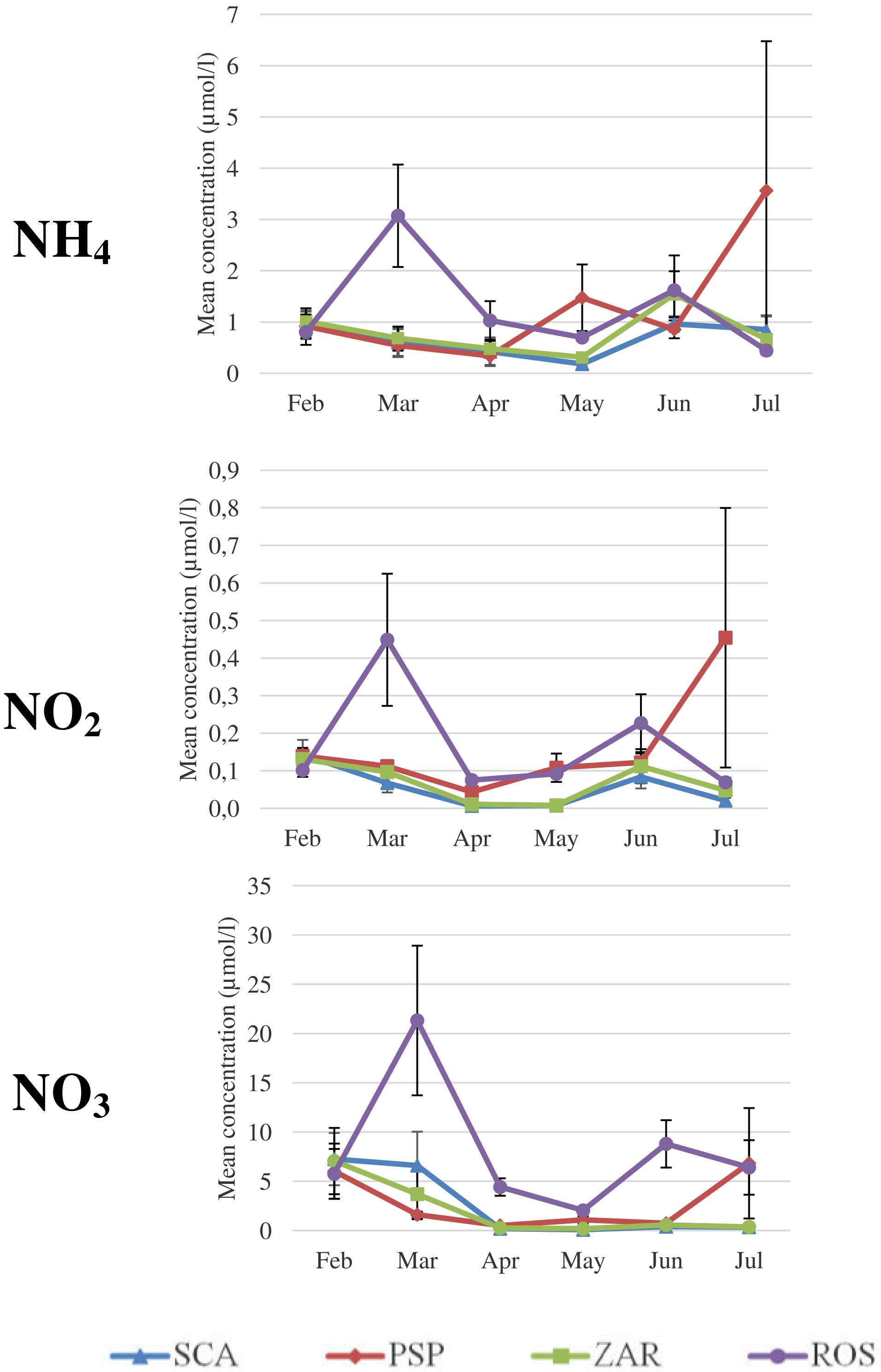


Figure 128: N nutrient concentrations (% coverage; mean±SE, n=5) of ammonia, nitrites, nitrates, phosphates and silicates for each site: Punta S. Pietro (PSP), Rocce di S. Anna (ROS), Zaro (ZAR), Scannella (SCA)

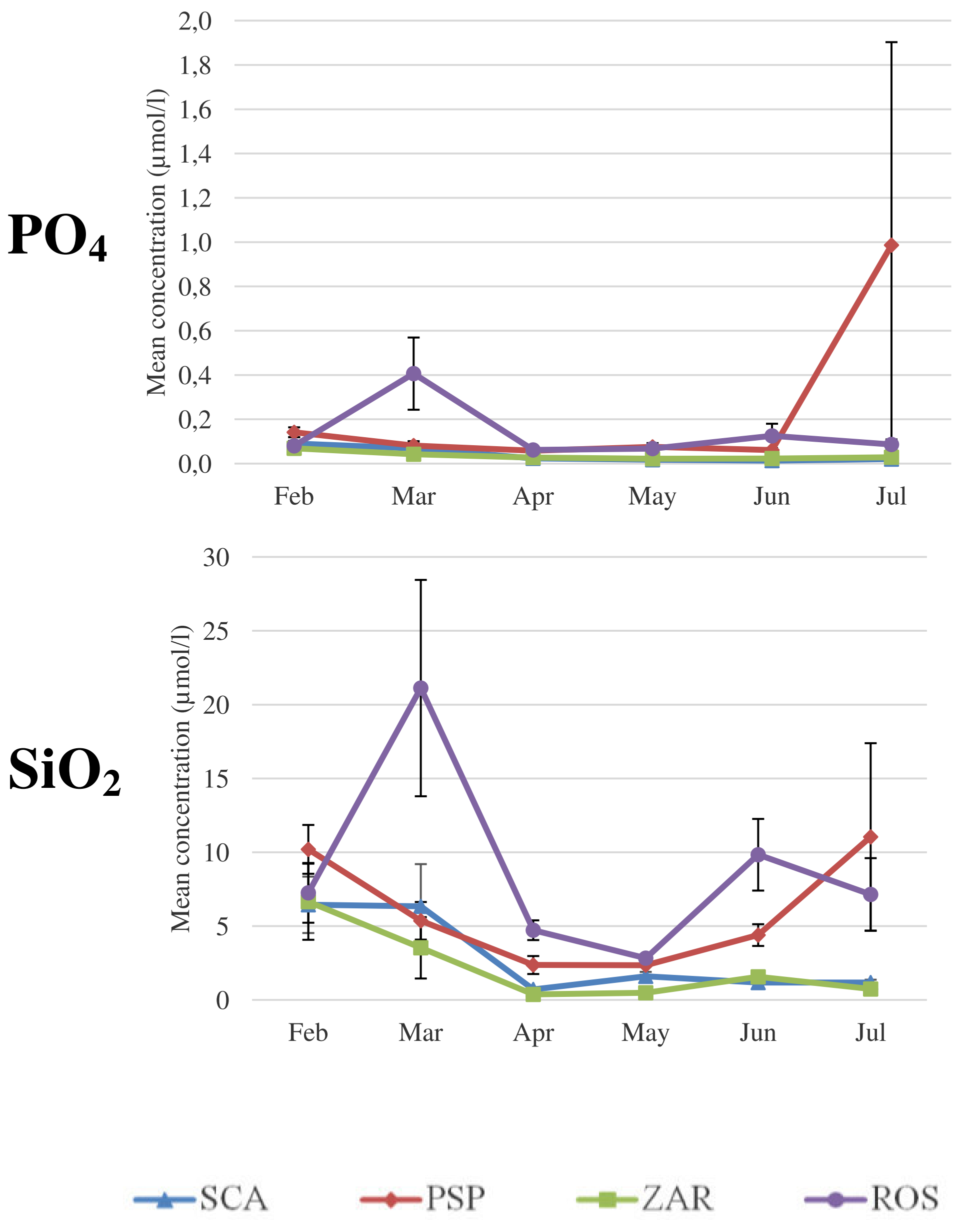


Figure 129: N nutrient concentrations (% coverage; mean±SE, n=5) of ammonia, nitrites, nitrates, phosphates and silicates for each site: Punta S. Pietro (PSP), Rocce di S. Anna (ROS), Zaro (ZAR), Scannella (SCA).

5.3.2 Rock-pool

The biggest rock-pool hosting the species, located in Scannella, extended for an area of about 8.6 m^2 with an average of 30 cm and a maximum depth of about 100 cm; the area is covered by different species and relative percentage is represented in Table 22 and Figure 130. The most abundant species was *C. compressa*, with the variety *C. compressa* var. *compressa* and the subspecies *C. compressa* subs. *pustulata*. Spots of *S. vulgare* were also present, but they seasonally disappeared during late summer and winter.

Table 22: Coverage of the species thriving in the biggest Scannella rock-pool

Species	Coverage (m^2)	%
C. brachycarpa	**1.36**	16.2
C. compressa	**5.04**	59.9
C. crinita	**1.96**	23.3
S. vulgare	**0.05**	0.59
TOTAL	8.41	100

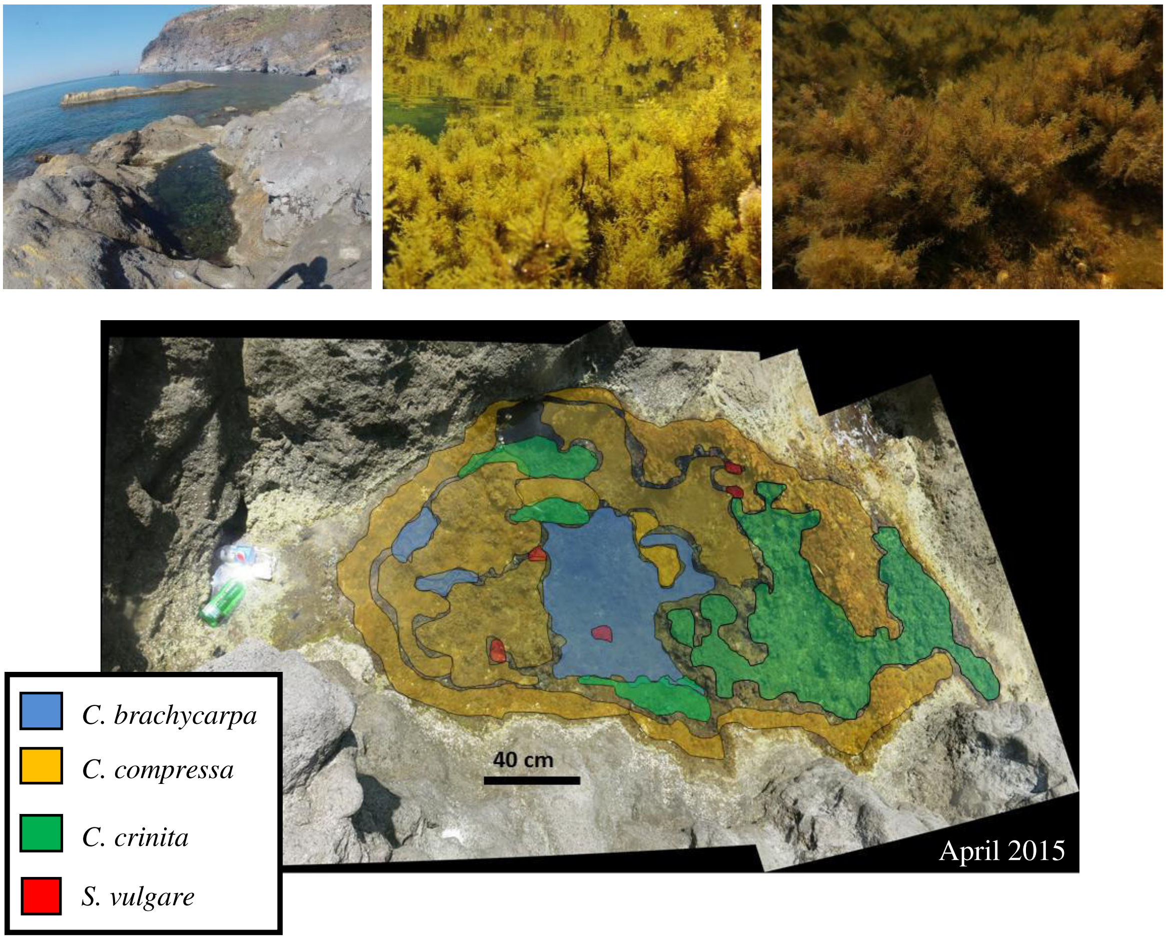


Figure 130: The biggest rock-pool of the Ischia Island (Scannella rock-pools) with different coverage of Fucales species. All the photos have been gathered in April 2015

5.3.3 Lower subtidal Forest

The continuity of *Cystoseira* distribution along transects at the Pietra Nera site varied between 70 and 100% in the period June 2015 and June 2016. The coverage assessed in 3 different periods in 2016 ranged between 69.4% in March and 83.3% in June (Figure 131A). The maximum canopy height of *C. brachycarpa* has been recorded in March (8.5 cm), while for *C. spinosa* in June (22.4 cm) (Figure 131B). The lowest biomass of *C. brachycarpa* was assessed in December (266.2 g/m^2 DW) and the highest in June (644.8 g/m^2) (Figure 131C). A rough estimation of the standing crop existing in the Pietra Nera station was assessed through the product between the surface occupied by the tuffaceous submerged rock (4000 m^2) and the biomass per square meter obtained within the quadrat. The Pietra Nera *Cystoseira* forest (Figure 132), contribute to the total organic matter of the system with the production of biomass values between 1.07 and 2.58 tons between December and June.

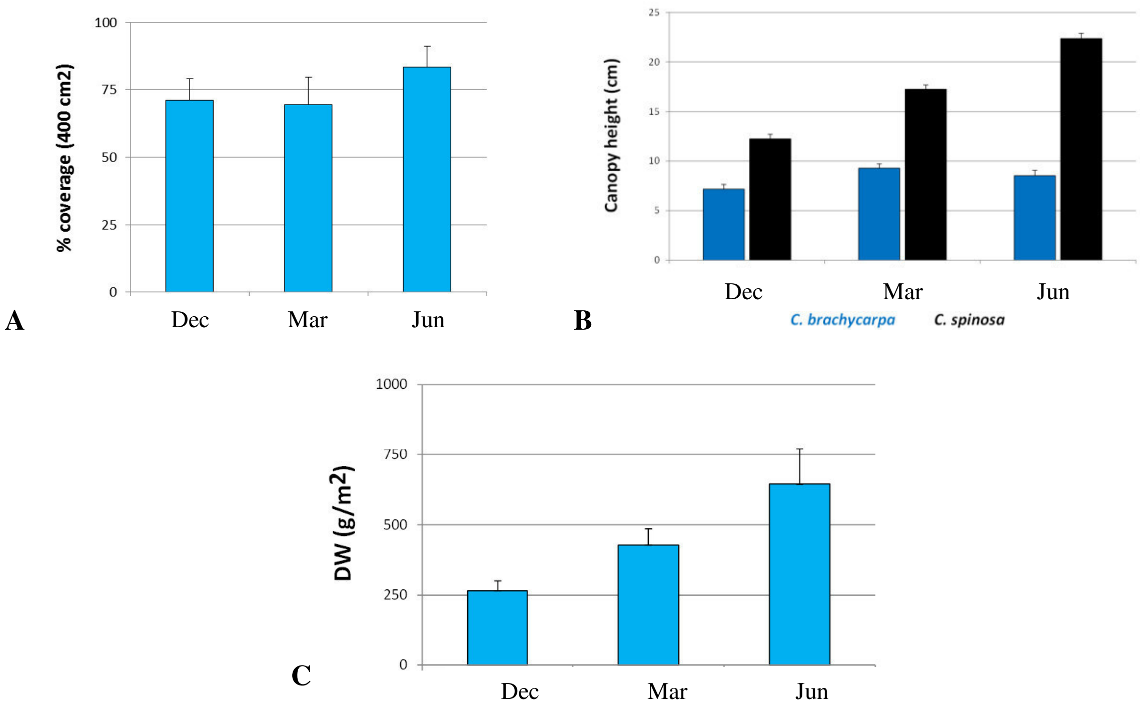


Figure 131: Seasonal phenological data of Fucales assemblages in Pietra Nera, Ischia. A) Coverage of *C. brachycarpa* assemblages (% coverage; mean±SE, n=9); B) Canopy height of the two species present in Pietra Nera: *C. brachycarpa* in blue and *C. spinosa* in black (cm; mean±SE, n=27). C) Dry weight (DW) of *C. brachycarpa* (g/m^{2}mean±SE, n=9)

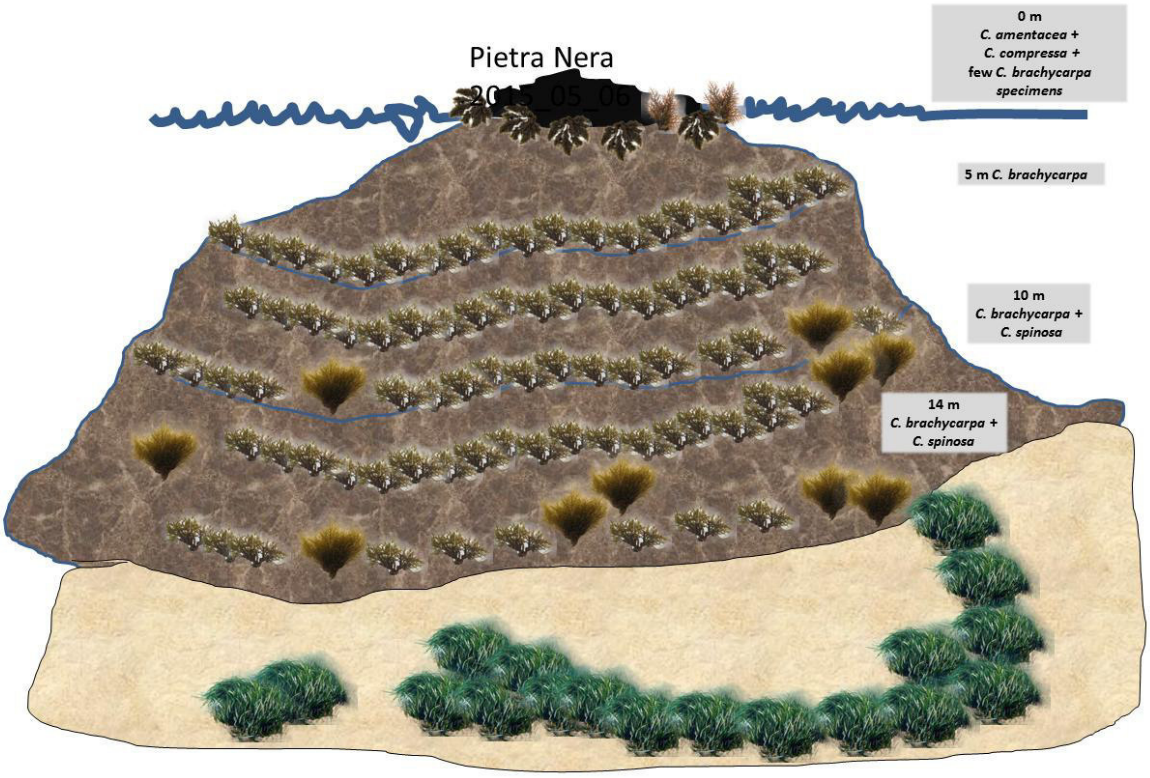


Figure 132: The two most abundant species recorded at Pietra Nera: *C. brachycarpa* (left) and *C. spinosa* var. *spinosa* (right)

5.4. Discussion

Highest values of continuity and coverage of *Cystoseira* spp. along the 12 stations are found at Punta Imperatore, Scannella and Castello Aragonese.

The quantitative assessment of *Cystoseira* populations around the island of Ischia evidenced also that the slope of the substrate seem to be one important environmental factor affecting continuity, coverage and species richness: low slope (between about 0 and 45°) generally means high continuity, high coverage and higher number of species.

C. compressa, the most abundant species occurring in all the 12 transects, has the highest values of canopy height in Castello Est and Pisciazza.

Data about the 6 stations re-surveyed after 2 years, evidenced a short term relative stability of the *Cystoseira* spp. belt in term of continuity along transects and coverage within quadrats.

Nutrient values of 4 different sites along the island displayed low values in general, with some exceptions. The values in Punta S. Pietro in July look higher than at the other sites, with some nutrient inputs during early spring (March) and early summer (June, July). In any case absolute values in all the stations were not so high to justify a disappearance or a decline of Fucales, as it has happened in Punta San Pietro in the last 30 years (Buia pers. comm.). The obtained nutrient data are lower compared to other data in literature where Fucales species thrive (Pinedo et al., 2015) and comparable with some data available for 2 Ischia sites of 15 years ago (Lorenti et al., 2005). In this publication one station (less than 100 m from the sewage outfall) with *C. mediterranea* coverage (same sensitivity of *C. amentacea*, i.e. very high) has nutrient values higher than 1 µmol/l, with peaks of 5 for nitrates. Comparing also ammonium values they are always higher than our results, with peaks of 33 µmol/l in August. Pinedo et al. (2015) conclude their work reporting that *C. mediterranea* seems to be adapted to extremely low dissolved nitrates in seawater being unable to resist the effects of heavy nitrates loading of 20 µmol/l, that, considering my monthly sampling design, was recorded only one times during the entire survey, only in one station.

These data evidenced that currently the nutrient enrichment can be excluded from the factors affecting the shallow population of Ischia, but without historical data on the past values of nutrients all along the island is impossible to exclude a past nutrient enrichment role (at least synergic) in the disappearance of *Cystoseira amentacea* in Punta San Pietro. However we can hypothesize that other factors such as scouring effect and turbidity generated by intense maritime traffic (the site is very close to the mouth of the main harbour of Ischia) could had an important role in this decline, but further studies are needed to explore these assumptions.

The map of Scannella rock-pool evidenced that in April the highly sensitive species *C. crinita* cover an area of about 25% of the entire pool. This species only thrive here with high coverage and in other 2 close (but more little) rock-pools in Scannella. The sites represent a unique place of dense occurrence reported for the entire Gulf of Naples.

Pietra Nera deep forest represent the site with the highest density of a *Cystoseira* species (i.e. *C. brachycarpa*, almost totally covering the rocky shore) and about 50 spotted specimens of *C. spinosa*. The sites represent a hotspot of biodiversity and biomass production that is incomparable in the entire study area and, as evidenced by some authors, could be exported in different habitats (Barreiro et al., 2011).

The preliminary data obtained in this study (continuity, coverage, canopy height, biomass, nutrient data) will represent a valid quantitative baseline for future assessment along Ischia stations (shallow habitat, rock-pool and deep forest).

The structural and functional role of Fucales is highly relevant when the stands are dense and continuous, like at the Pietra Nera. Here indeed, a huge biomass of organic matter, can be partially available for the contiguous ecosystem or exported (being *Cystoseira* a deciduous species) and representing an amount of food or shelter with a complex three dimensional habitat for many organisms.

A continuous monitoring programme of these stations could be helpful for the next future in the detection of slight changes as early warning signals: an ecological indicator until molecular and microbiological tools will be developed for these species.

The results obtained in this Chapter will provide a valid clear reference point for future temporal assessment of the species, that could be possibly implemented and integrated with physiological, phenotipical and reproductive studies, for example with the response of global change through transplant of model species (i.e. *C. amentacea*, *C. brachycarpa*, *S. vulgare*) in the acidified site of Castello Aragonese, as literature seems to show different pattern of response of Fucales to ocean acidification (Bellissimo et al., 2014; Baggini et al., 2014; Porzio et al., 2017; Kumar et al., 2017).

Moreover, it is expected that the future conditions will be different considering that the treatment plants of the island will hopefully be increase and will go soon into operation. Despite this possible trend, many other assemblages are under increased threat.

The biodiversity hot-spot of Scannella site is susceptible of disturbance since the ongoing development of a beach club that year by year is increasing its surface and spreading along the coastline, directly discharging sewage into the sea (about 100 m apart) and adding concrete, with the aim to flatten the coast for touristic purpose (i.e. solarium, artificial swimming pools). This disturbance will probably increase in the future considering the shift activity from beach club to hotel accommodation recently occurred here and this case is worth of consideration.

Finally, in the near future, new surveys should be considered also for the northern side of Ischia in order to evaluate possible propagation of the species from surrounding areas.

6. Top-down pressures

6.1 Introduction

The Fucales assemblages in the Gulf of Naples experienced different types of stressors from the beginning of the 20th century to nowadays. These stressors (with huge impacts at different levels of biological organization) can be distinguished in biotic (e.g., grazing, competition with other species) and abiotic threats (e.g. eutrophication, chemical pollution, scouring). Many authors stressed the importance of these factors in the loss, maintenance and restoration of Fucales (Airoldi & Beck, 2007; Mangialajo et al., 2008; Verges et al., 2009; Thibaut et al., 2015a,; Pinedo et al., 2015).

The main result from the revision of the pressures and impacts in the Gulf of Naples (Chapter 2) is the lack of a continuous and long temporal series of data on biotic and abiotic processes (i.e. grazing pressure and nutrients). This is especially true in those sites that, in spite of being far from the metropolitan area, have experienced, over the last 50-60 years, an intense coastal development, such as the islands of Ischia and Procida (Sector A). In this sector, the highest Fucales diversity is present. In many of these sites, shallow and deep Historical Records were completely erased (Chapter 3). The northern shallow seafloor of Ischia lost many suitable habitats for these species, today replaced by artificial barriers or concrete structures or disconnected from natural habitats. Vivara Island seascapes, 40 years ago, were described to host a well-developed belt of *C. mediterranea, Balanus perforatus* and *Mytilus galloprovincialis* (Cinelli, 1976b). All around the island, at 7-10 m depth, the species *C. crinita* was among the most abundant species, but today has totally disappeared. Despite the present evaluation of coastal changes, we could not obtain information about all the abiotic, biotic factors possibly involved in such declines and their historical dynamics. Barren grounds due to sea urchins overgrazing that could have occurred at local scale in different zones of the gulf were not found in this study. Analogously, there is no evidence of increases of herbivorous fishes such as *Sarpa salpa* in the last 100 years, but observations around the Ischia CO_2 vents suggest an increased grazing pressure by this species in acidified conditions (Garrard, 2013; Scipione & Garrard, 2013; Scipione et al., 2015). Moreover, an increased abundance of the meso-grazer *Ampithoe raimondi* is reported in acidified waters

(Scipione pers. comm.). This species belongs to a family of Amphipoda theoretically feeding on macroalgae, as indicated by extra-Mediterranean literature and normally explained with the effect of higher acidification leading to higher grazing activity of this group. Finally, the competition of Fucales with other species, possibly coupled with increased nutrients, higher turbidity, organic matter inputs due to sewage outfall may also play a role in the decline of these habitat-forming species. Within this complex context, we focused our attention on grazing as one of the most likely processes driving the documented depletion of *Cystoseira* spp.

Sea urchins represent a main food item for Sparid fishes (i.e., *Diplodus* spp.) (Guidetti, 2006) which can, therefore, exert a strong control over sea urchin populations (Sala et al., 1998). Sea urchins, when at high densities, can remove large patches of erect algae and induce the formation of coralline barrens (Verlaque, 1987). Currently, the Mediterranean Sea is very far from its pristine condition, also due to a long history of fishing. Specifically, small to medium-sized consumers (e.g. sea breams) are the most abundant and biggest predators left, thus representing the main actors shaping coastal benthic communities. On the contrary, historical reconstructions depict abundant populations of large carnivorous fishes, including sharks (top predators), in coastal areas (Prato et al., 2013).

Taking into account the relative abundance of Fucales and their frequency of occurrence during the present surveys, the most common upper subtidal species were *C. compressa* and *C. amentacea*. Sea urchins seem to have different patterns of correlation with these two species, tending to be more abundant in the presence of *C. amentacea* and less abundant in the presence of *C. compressa* (Mulas, 2013). Nevertheless, the actual cause/effect relationships have not yet been clarified; it could be predicted, however, that such patterns are related to a different level of human harvesting of sea urchins in areas dominated by these algal species, or to a different their palatability.

Sea urchins are usually considered generalist herbivores (Verlaque, 1987; Cacabelos et al., 2010), but some preference behaviours were reported (Neil & Pastor, 1973; Boudouresque & Verlaque, 2001). It is noted, in particular, that sea urchins can actively select for some seaweed species over others, possibly due to the nutritive value and physical/chemical properties of different food items (Frantzis & Gremare, 1992). Some studies on feeding behaviour have demonstrated a non-random association between grazers and macroalgae (Strong et al., 2009; Monteiro et al., 2009). Food preference in *P. lividus* has been mostly assessed through aquarium experiments, where individuals were exposed to two items in similar and non-limiting amounts (reviewed by Boudoresque & Verlaque, 2001). Further information on this topic come from comparisons of the abundance of each type of food in the gut content of urchins and the diversity of the habitat in which individuals were collected (Boudoresque & Verlaque, 2001).

In the study area, a third species of Fucales, *C. brachycarpa*, was found as the most frequent in the lower subtidal (Chapter 4). In the most dense *C. brachycarpa* stand (Pietra Nera, Sector A), sea urchins showed locally very big size and relatively high densities (about 10-12 m^2). Anyway, we did not find densities of *P. lividus* that are known to determine the formation of barren grounds (Verlaque, 1984; Orlando-Bonaca & Mavric, 2014).

A common food item for sea urchins is the seagrass *Posidonia oceanica*. It is also widespread in the study area (Ischia, Sector, A), with a very high coverage between 1 and 35 m depth. In Mediterraean Sea, it creates the most frequent habitat within this bathymetrical range, where it commonly coexists with *Cystoseira* spp.

In order to test whether higher palatability of some macrophytes could be responsible for a higher intensity of grazing and, consequently, of their regression, feeding preference experiments were conducted, following the experimental approach of Cacabelos et al. (2010), modified according to the specific hypotheses and type of data involved in the present study. Experiments were performed in the laboratory with the sea urchin *P. lividus*, a keystone herbivore species of Mediterranean rocky assemblages (Tomas et al., 2010). Four different food items (*C. amentacea*, *C. brachycarpa*, *C. compressa*, *P. oceanica*) were offered either alone or paired. Food consumption in each single *vs.* combined condition, as well as the chemical content of each macrophyte, were analysed.

6. 2 Material and methods

Three fucoid species *C. amentacea* (CA), *C. compressa* (CC), *C. brachycarpa (*CB), and one seagrass *P. oceanica* (PO) were chosen for the experiment. The first two species formed shallow intertidal belts around the Ischia Island, but are known to have different ecological sensitivity (Mangialajo et al., 2008). *Cystoseira brachycarpa* is the most widespread lower subtidal fucoid species in the study area and it occurs at the same depth range (3-25m) of *P. oceanica*, the most common seagrass in the area.

Feeding assays were performed using fresh pieces of macrophytes collected from the same area to avoid variation in physical and chemical properties among populations of each species. All the species used in the experiment were collected the same day in order to reduce possible changes in their chemical content after detachment, and were kept in tanks with flowing seawater until the start of the subsequent experimental manipulations. The same portion of the plants were offered to grazers: median-apical fronds for *Cystoseira* spp. and intermediate green leaves (2^{nd} or 3^{rd} in the shoot) for *P. oceanica*, in order to avoid differences in toughness and chemical contents (see also Cacabelos et al., 2010).

P. lividus was chosen for being a generalist herbivore and one of the few organisms feeding on *P. oceanica* leaves. Sea urchins were collected from the same site (in front of the lab) in order to avoid any additional stress, kept in tanks, and starved 2 days before the experiment. According to Pavia et al. (1999) individuals of similar size were used to minimize feeding differences. A mean test diameter of 40 mm, corresponding to 4-5 years age (Verlaque, 1984; Boudoresque & Verlaque, 2001) was selected.

The tanks with plants and sea urchins were maintained at the natural seawater temperature (about 19°C) in an open aerated system exposed to natural light-dark cycle. Feeding assays were conducted in late May-beginning of June, when all the *Cystoseira* species were abundant.

The following two experimental conditions (levels of 'treatment') were established according to the number of macrophytes (one or two) offered to a single individual of *P. lividus*: 'single' (each species presented alone) and 'combined' (all possible pairs). For each of these conditions, the proportional consumption of each species when presented either alone or associated to another species was estimated after 24 h. Such estimates were calculated by comparing the weight of each piece before and after the experimental period (blotted weight, BW), after correcting for the autogenic loss of biomass estimated from other control tanks where the same experimental treatments were established, but without grazers (Cronin & Hay, 1996). The total macrophyte biomass (3 g) offered to the grazer at the beginning of the experiment was the same in 'single' and 'combined' levels. The experiment was repeated twice (hereafter indicated as Run1 and Run2). Each repetition of the experiment consisted of a net breeder of 3.5 l (transparent PVC aquaria) where each single-macrophyte or combined-macrophytes treatment was offered to one sea urchin separately. Three tanks (approximately 500 l each) for each set of interspersed treatments and experimental repetitions were used and filled with aquaria (Figure 133).

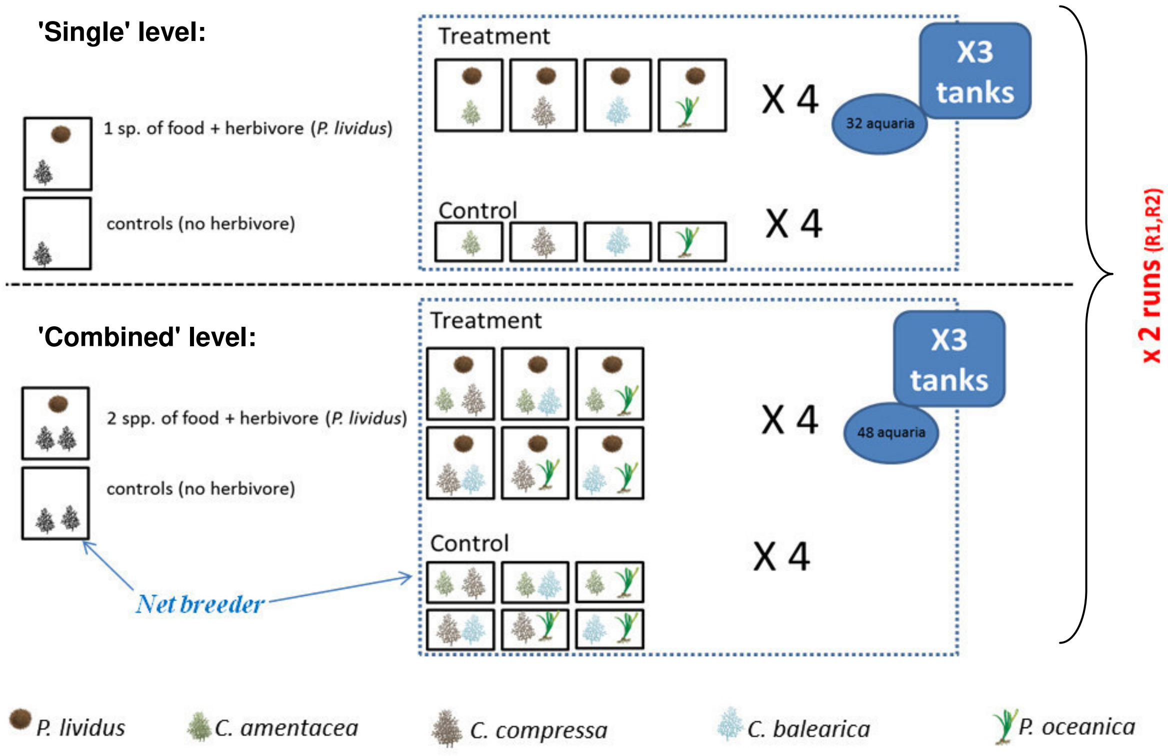


Figure 133: Feeding choice experimental design, composed by 'single' and 'combined' level of treatment

At the beginning and at the end of the feeding experiments six small parts (about 2 g FW) of each macrophyte were collected for the analysis of the Total Phenolic Content. According to

Singleton & Rossi (1965), who modified the Folin-Ciocalteau's procedure, the total phenolic content was calculated and expressed in terms of mg of gallic acid equivalents (GAE) per g of dry weight (DW).

Furthermore, Total C and N contents of macrophytes were determined by combustion. The analyses were performed with a Thermo Scientific FlashEA 1112 automatic elemental analyser (Thermo Fisher Scientific, Waltham, MA, USA), following the procedure described by Hedges & Stern (1984). Acetanilide was used as standard.

Statistical analysis

The quantity of each plant tissue consumed by sea urchins was derived from the difference between the BW measured in each treatment before and after the grazing activity (24 h experimental period).

For each species, a set of three analyses of variance (ANOVA) were performed, based on a three-way model including the following factors: *Treatment* ('single vs. 'combined', corresponding to that species presented alone or together with one of the other three species, respectively), fixed; *Tank* (3 levels, orthogonal and random); *Run* (2 levels, orthogonal to both Treatment and Tank), random. The absence of a preference (null hypothesis, H_0) for one type of food compared to each other would be identified by a similar proportion of that item consumed when presented alone and when presented together with another item (Table 23). The interaction Treatment x Tank x Run was examined to test for the consistency of the possible grazer's preference among different tanks and between experimental repetitions.

Table 23: Example of H_0 hypothesis of no preference of one macrophyte species, when offered alone (Sp. 1) or in combination with another species (Sp.2, Sp.3 or Sp.4). Each H_0 hypothesis applies to all 4 species (CA, CB, CC, PO) examined.

Ho: No preference of Sp.1 among other 3 species (Sp.2, Sp.3 or Sp.4)

- Sp.1 = Sp.1-Sp.2
  The proportion of Sp.1 consumed when presented alone is equal to the Sp.1 proportion consumed when presented together with Sp.2
- Sp.1 = Sp.1-Sp.3
  The proportion of Sp.1 consumed when presented alone is equal to the Sp.1 proportion consumed when presented together with Sp.3
- Sp.1 = Sp.1-Sp.4
  The proportion of Sp.1 consumed when presented alone is equal to the Sp.1 proportion consumed when presented together with Sp.4

Unfortunately, some replicates were lost during the experiment. Missing replicates were replaced by the average of the remaining replicates in the corresponding combination of factor levels and the degrees of freedom were adjusted as appropriate. For each ANOVA the assumption of homogeneity of variances was tested with Cochran's C test and data were transformed when necessary. When heterogeneous variances could not be stabilized by transformation, data were left untransformed and non-significant results were interpreted as robust (Underwood, 1997). The Student-Neuman-Keuls (SNK) test was used for *post hoc* comparisons of means, were relevant. In addition, a two-way ANOVA was performed to test any differences in polyphenolic content among macrophytes (4 levels: CA, CB, CC, PO) and sampling times (2 levels, before and after feeding experiment).

6.3 Results

The percentage of consumption among replicates varied between 1% and 53% when the item was offered alone and between 0.2% and 83% when in combination with another species. The overall average consumption of *P. lividus* was about 0.356 g (BW). The mean percentage of auto-consumption of each species varied between a minimum of 4.32% in CA to a maximum of 8.19% in CBR (Figure 134). These differences have been used, separately for each experimental condition, to correct the weights actually consumed by the grazers.

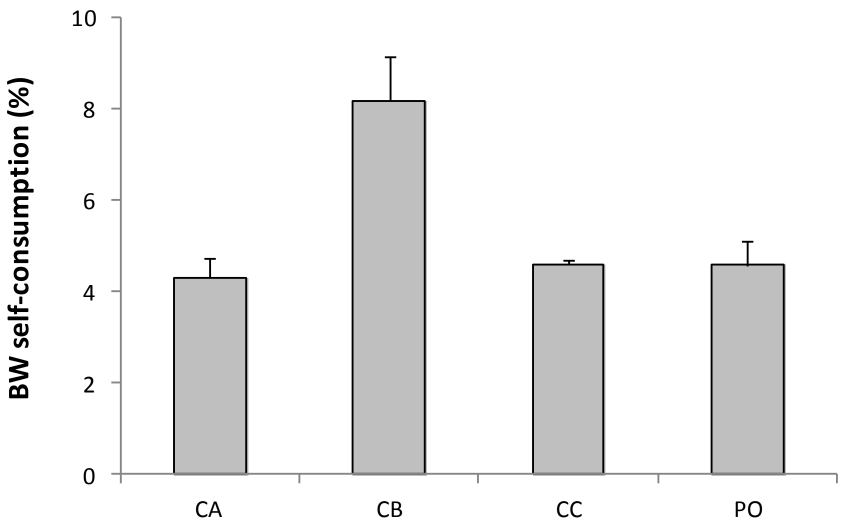


Figure 134: Self-consumption per each species (% of total weight; mean ±SE, n=96)

P. lividus showed no wide preference for any of the food items, as indicated by the total 12 ANOVA documenting, in most cases, either non-significant tests or significant effects of the treatment (Tr) varying depending on tanks (Ta) and/or runs (Ru). The only consistent (across all tanks and runs) significant result is the higher consumption of PO when presented alone compared to when it was presented together with CA (Table 24). The ANOVA results for each comparison (one species alone versus two species together) are shown in Tables 25-36 and the eaten proportion (expressed as the percentage of consumption) in each combination of experimental factors are displayed in Figures 135-146, including the results of relevant *post hoc* SNK tests.

Table 24: Summary of significant results of ANOVA tests on the sea urchin's preference (*=p<0.05; **=p<0.01)

Single level:		Combined level:	ANOVA result	Pattern of consumption	Factor levels combination
CA	*vs.*	CA-CB	No signif. results		
CA	*vs.*	CA-CC	No signif. results		
CA	*vs.*	CA-PO	TrxTaxRu	CA < CA-PO	Ta2-Ru1**
CB	*vs.*	CB-CA	TrxTaxRu	CB > CB-CA	Ta1Ru2*; Ta3Ru1**
CB	*vs.*	CB-CC	No signif. results		
CB	*vs.*	CB-PO	No signif. results		
CC	*vs.*	CC-CA	No signif. results		
CC	*vs.*	CC-CB	TrxRu	CC > CC-CB	Ru2*
CC	*vs.*	CC-PO	Tr xTaxRu	CC > CC-PO	Ta1Ru2**; Ta2Ru2*
PO	*vs.*	PO-CA	Treatment	PO > PO-CA	Tr*
PO	*vs.*	PO-CB	No signif. results		
PO	*vs.*	PO-CC	No signif. results		

Table 25: Results of three way ANOVA between CA *vs*. CA-CB

Source	DF	MS	*F*	*F versus*
Tr	1	557.4850	2.00	TrXRu [b]
Ta	2	111.1946	0.71	TaXRu
Ru	1	468.6026	2.99	TaXRu
TrXTa	2	55.3061	1.36	TrXTaXRu
TrXRu	1	279.2121	6.85	TrXTaXRu
TaXRu	2	156.6692	1.17	RES
TrXTaXRu	2	40.7876	0.31	RES
RES	36	133.6898		

Cochran's test: *C= 0.209* (p>0.05)
Transformation: None

b=tested over the TrxRu MS after elimination of the TrxTa term which was not significant at p>0.25

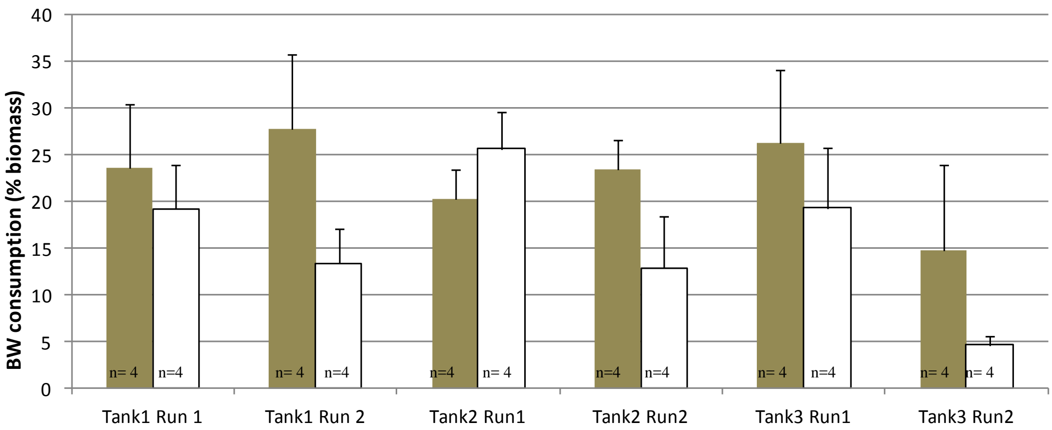


Figure 135: Proportion (mean+SE) of *C. amentacea* consumed when presented alone (grey) or together with *C. brachycarpa* (white) in each combination of Tank and Run. The numbers (n) at the bottom of each bar indicate the replicates used to calculate each mean

Table 26: Results of three way ANOVA between CA *vs*. CA-CC

Source	DF	MS	*F*	*F versus*
Tr	1	10.8689	0,01	TrXRu [b]
Ta	2	184.3687	1.85	TaXRu
Ru	1	1528.6665	15.36	TaXRu
TrXTa	2	105.564	0.44	TrXTaXRu
TrXRu	1	1166.9449	4.84	TrXTaXRu
TaXRu	2	99.5504	0.63	RES
TrXTaXRu	2	241.1631	1.53	RES
RES	35 [a]	161.9414		

Cochran's test: *C= 0.176* (p>0.05)
Transformation: None

a=Degrees of Freedom corrected for missing data
b=tested over the TrxRu MS after elimination of the TrxTa term which was not significant at p>0.25

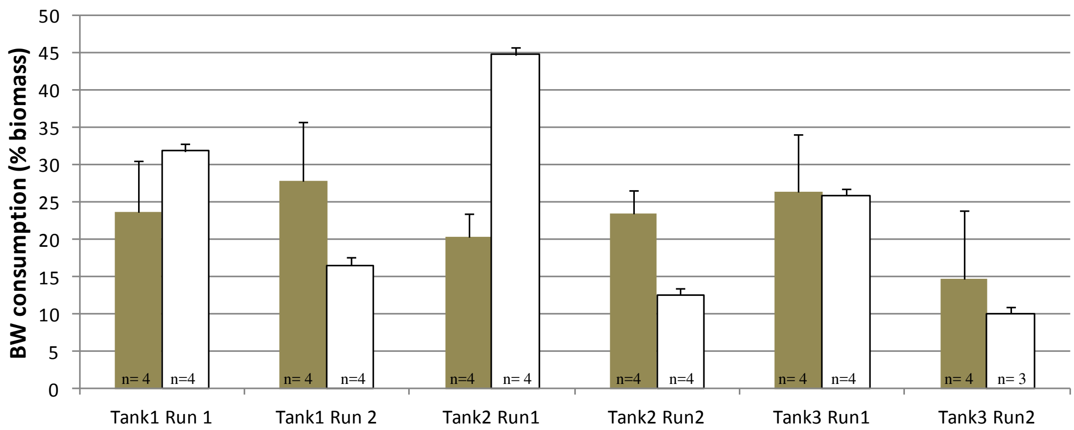


Figure 136: Proportion (mean+SE) of *C. amentacea* consumed when presented alone (grey) or together with *C. compressa* (white) in each combination of Tank and Run. The numbers (n) at the bottom of each bar indicate the replicates used to calculate each mean

Table 27: Results of three way ANOVA between CA *vs.* CA-PO (*=p<0.05; **=p<0.01; ***=p<0.001)

Source	DF	MS	*F*	*F versus*
Tr	1	233.8166	0.00	NO TEST
Ta	2	448.7266	0.74	TaXRu
Ru	1	2202.9484	3.63	TaXRu
TrXTa	2	195.0617	0.27	TrXTaXRu
TrXRu	1	1763.8310	2.47	TrXTaXRu
TaXRu	2	606.2550	3.06	RES
TrXTaXRu	2	714.6332	3.61*	RES
RES	35 [a]	197.9533		

Cochran's test: *C*= 0.178 (p>0.05)
Transformation: None

a=Degrees of Freedom corrected for missing data

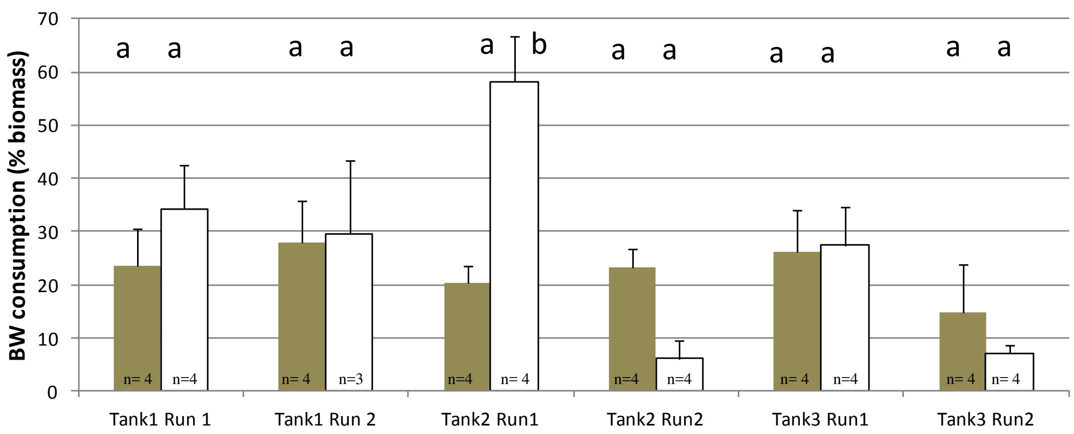


Figure 137: Proportion (mean+SE) of *C. amentacea* consumed when presented alone (grey) or together with *P. oceanica* (white) in each combination of Tank and Run. Different lowercase letters above bars indicate significantly different means according to SNK test. Note: only comparisons between treatment levels in each combination of Tank and Run are appropriate. The numbers (n) at the bottom of each bar indicate the replicates used to calculate each mean

Table 28: Results of three way ANOVA between CB *vs*. CB-CA (*=p<0.05; **=p<0.01; ***=p<0.001)

Source	DF	MS	*F*	*F versus*
Tr	1	5.2500	0.00	NO TEST
Ta	2	1.8870	2.39	TaXRu
Ru	1	5.5235	7.00	TaXRu
TrXTa	2	0.3805	0.23	TrXTaXRu
TrXRu	1	0.0091	0.01	TrXTaXRu
TaXRu	2	0.7887	1.80	RES
TrXTaXRu	2	1.6827	3.84*	RES
RES	34[a]	0.4386		

Cochran's test: *C*= 0.299 (p>0.05)
Transformation: Ln(X+1)

a=Degrees of Freedom corrected for missing data

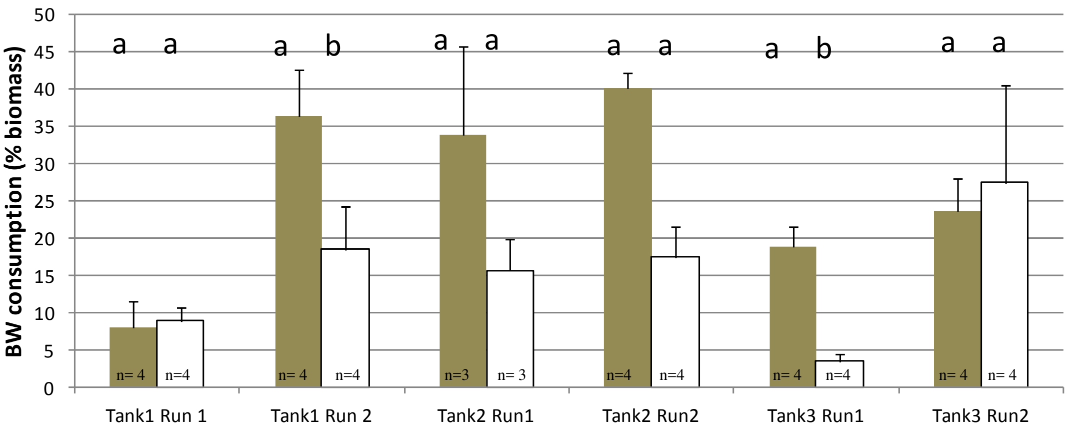


Figure 138: Proportion (mean+SE) of *C. brachyarpa* consumed when presented alone (grey) or together with *C. amentacea* (white) in each combination of Tank and Run. Different lowercase letters above bars indicate significantly different means according to SNK test. Note: only comparisons between treatment levels in each combination of Tank and Run are appropriate. The numbers (n) at the bottom of each bar indicate the replicates used to calculate each mean

Table 29: Results of three way ANOVA between CB *vs.* CB-CC

Source	DF	MS	*F*	*F versus*
Tr	1	587.4804	2.28	RES[b]
Ta	2	346.0743	0.42	TaXRu
Ru	1	1718.8376	2.08	TaXRu
TrXTa	2	290.7399	10.69	TrXTaXRu
TrXRu	1	14.6286	0.54	TrXTaXRu
TaXRu	2	825.7291	3.21	RES
TrXTaXRu	2	27.2085	0.11	RES
RES	35[a]	257.1320		
TOT	46			

Cochran's test: *C= 0.313* (p>0.05)
Transformation: None

a=Degrees of Freedom corrected for missing data
b=tested over the TrxRu MS after elimination of the TrxTa term which was not significant at p>0.25

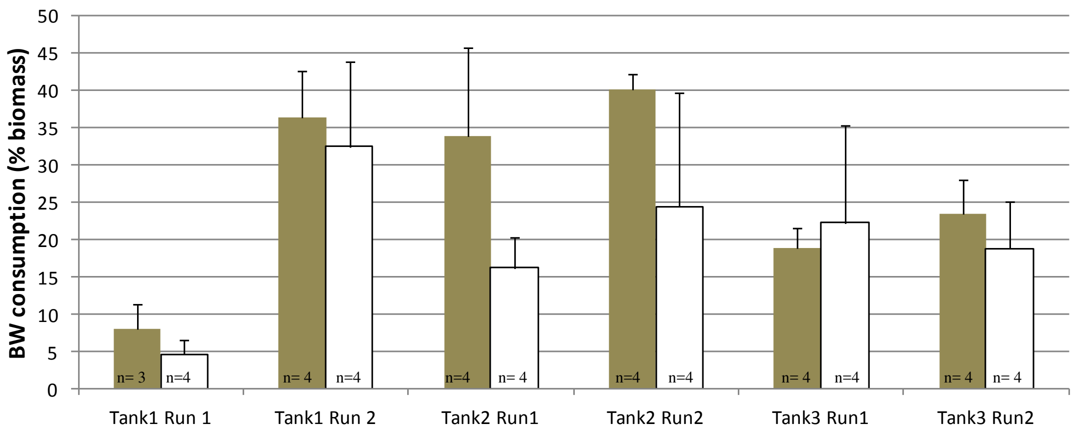


Figure 139: Proportion (mean+SE) of *C. brachyarpa* consumed when presented alone (grey) or together with *C. compressa* (white) in each combination of Tank and Run. The numbers (n) at the bottom of each bar indicate the replicates used to calculate each mean

Table 30: Results of three way ANOVA between CB *vs*. CB-PO (*=p<0.05; **=p<0.01; ***=p<0.001)

Source	DF	MS	*F*	*F versus*
Tr	1	253.7924	0.90	TrXTaXRu[b]
Ta	2	282.0878	0.25	TaXRu
Ru	1	393.3461	0.35	TaXRu
TrXTa	2	582.6800	2.06	TrXTaXRu
TrXRu	1	647.7357	2.29	TrXTaXRu
TaXRu	2	1122.4817	8.52***	RES
TrXTaXRu	2	282.3023	2.14	RES
RES	36	131.7249		

Cochran's test: *C* = 0.2568 (p>0.05)
Transformation: None

b=tested over the TrxRu MS after elimination of the TrxTa term which was not significant at p>0.25

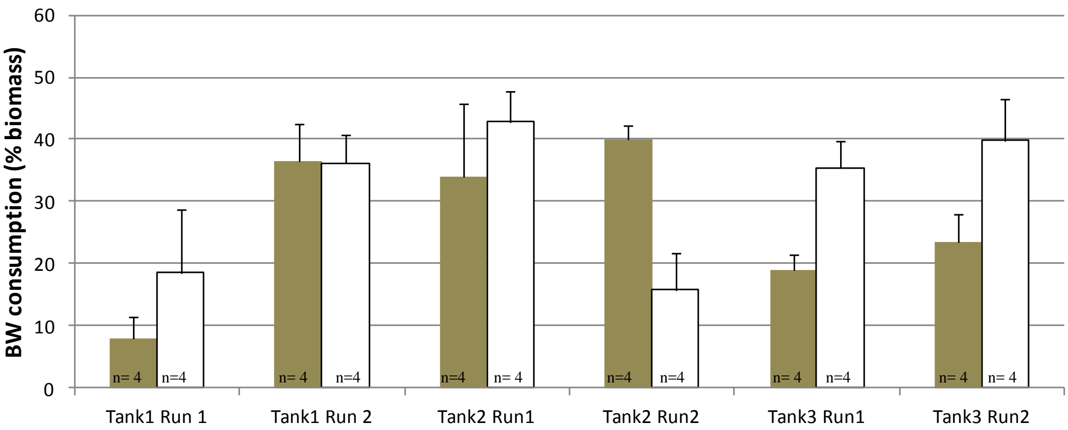


Figure 140: Proportion (mean+SE) of *C. brachyarpa* consumed when presented alone (grey) or together with *P. oceanica* (white) in each combination of Tank and Run. The numbers (n) at the bottom of each bar indicate the replicates used to calculate each mean

Table 31: Results of three way ANOVA between CC *vs*. CC-CA (*=p<0.05; **=p<0.01; ***=p<0.001)

Source	DF	MS	*F*	*F versus*
Tr	1	78.9560	4.72	TrXTaXRu[b]
Ta	2	0.0132	0.01	TaXRu
Ru	1	2.8580	19.49*	TaXRu
TrXTa	2	1.7757	1.06	TrXTaXRu
TrXRu	1	2.1531	1.29	TrXTaXRu
TaXRu	2	1.1215	1.02	RES
TrXTaXRu	2	1.6730	1.52	RES
RES	34[a]	1.0982		

Cochran's test: *C* =0.295 (p>0.05)
Transformation: Sqrt(X+1)

a=Degrees of Freedom corrected for missing data
b=tested over the TrxRu MS after elimination of the TrxTa term which was not significant at p>0.25

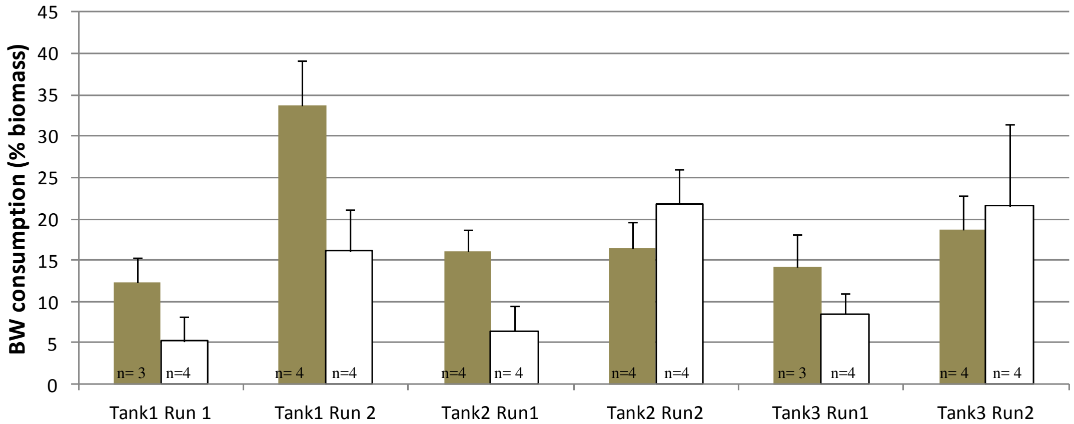


Figure 141: Proportion (mean+SE) of *C.compressa* consumed when presented alone (grey) or together with *C. amentacea* (white) in each combination of Tank and Run. The numbers (n) at the bottom of each bar indicate the replicates used to calculate each mean

Table 32: Results of three way ANOVA for the comparison CC *vs*. CC-CB (*=p<0.05; **=p<0.01; ***=p<0.001)

Source	DF	MS	*F*	*F versus*
Tr	1	503.8453	0.60	TrXRu[b]
Ta	2	45.9875	0.16	TaXRu
Ru	1	1.8620	0.01	TaXRu
TrXTa	2	101.7351	2.99	TrXTaXRu
TrXRu	1	840.9595	24.70*	TrXTaXRu
TaXRu	2	288.7000	3,69*	RES
TrXTaXRu	2	34.0408	0,44	RES
RES	33[a]	78.2448		

Cochran's test: *C* = 0.305 (p>0.05)
Transformation: None

a=Degrees of Freedom corrected for missing data
b=tested over the TrxRu MS after elimination of the TrxTa term which was not significant at p>0.25

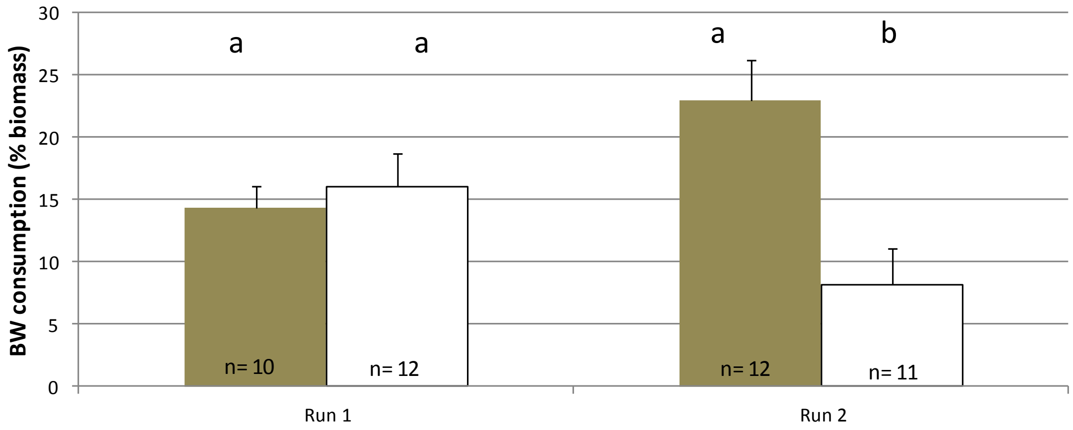


Figure 142: Proportion (mean+SE) of *C. compressa* consumed when presented alone (grey) or together with *C. brachycarpa* (white) in each Run. Different lowercase letters above bars indicate significantly different means according to SNK test. Note: only comparisons between treatment levels in each Run are appropriate. The numbers (n) at the bottom of each bar indicate the replicates used to calculate each mean

Table 33: Results of three way ANOVA between CC *vs*. CC-PO (*=p<0.05; **=p<0.01; ***=p<0.001)

Source	DF	MS	*F*	*F versus*
Tr	1	400.8875	0.00	NO TEST
Ta	2	38.5903	0.16	TaXRu
Ru	1	34.3808	0.14	TaXRu
TrXTa	2	239.6711	0.99	TrXTaXRu
TrXRu	1	600.2660	2.48	TrXTaXRu
TaXRu	2	240.1118	4.01*	RES
TrXTaXRu	2	241.6000	4.04*	RES
RES	33[a]	59.4876		
TOT	44			

Cochran's test: C = 0.255 (p>0.05)
Transformation: None

a=Degrees of Freedom corrected for missing data

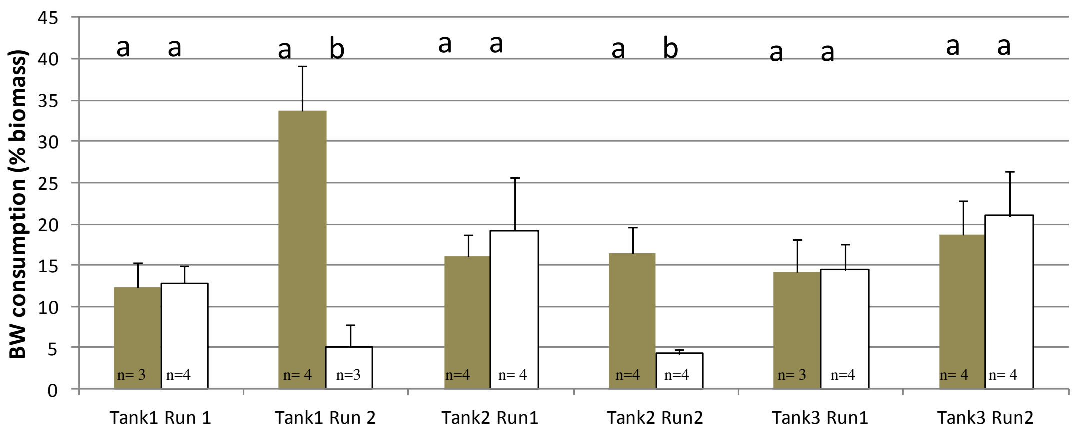


Figure 143: Proportion (mean+SE) of *C. compressa* consumed when presented alone (grey) or together with *P. oceanica* (white) in each combination of Tank and Run. Different lowercase letters above bars indicate significantly different means according to SNK test. Note: only comparisons between treatment levels in each combination of Tank and Run are appropriate. The numbers (n) at the bottom of each bar indicate the replicates used to calculate each mean

Table 34: Results of three way ANOVA between PO *vs*. PO-CA (*=p<0.05; **=p<0.01; ***=p<0.001)

Source	DF	MS	*F*	*F versus*
Tr	1	2.244,5816	18.74*	TrXTaXRu[b]
Ta	2	132,2421	96.65*	TaXRu
Ru	1	327,2430	239.16**	TaXRu
TrXTa	2	47,2053	0.39	TrXTaXRu
TrXRu	1	272,0853	2.27	TrXTaXRu
TaXRu	2	1,3683	0,03	RES
TrXTaXRu	2	119,7720	2,29	RES
RES	23^a	52,2720		

Cochran's test: C = 0.261 (p>0.05)
Transformation: None

a=Degrees of Freedom corrected for missing data
b=tested over the TrxTaxRu MS after elimination of the TrxTa, TrxRu terms which were not significant at p>0.25

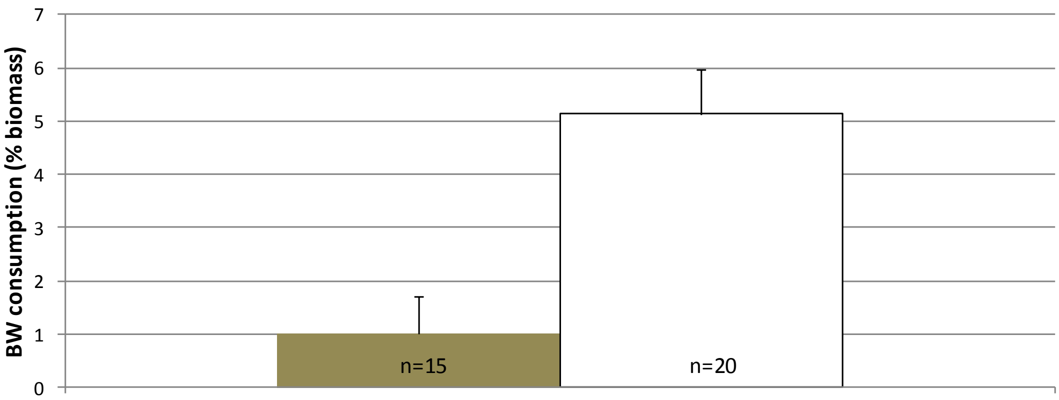


Figure 144: Proportion (mean+SE) of *P. oceanica* consumed when presented alone (grey) or together with *C. amentacea* (white). The numbers (n) at the bottom of each bar indicate the replicates used to calculate each mean

Table 35: Results of three way ANOVA between PO *vs*. PO-CB (*=p<0.05; **=p<0.01; ***=p<0.001)

Source	DF	MS	*F*	*F versus*
Tr	1	29.7147	4.47	TrXRu[b]
Ta	2	4.4400	38.65*	TaXRu
Ru	1	2.3429	20.39*	TaXRu
TrXTa	2	1.7935	1.24	TrXTaXRu
TrXRu	1	6.6413	4.59	TrXTaXRu
TaXRu	2	0.1149	0.10	RES
TrXTaXRu	2	1.4478	1.22	RES
RES	24[a]	1.1856		

Cochran's test: *C* = 0.317 (p>0.05)
Transformation: Sqrt(X+1)

a=Degrees of Freedom corrected for missing data
b=tested over the TrxRu MS after elimination of the TrxTa term which was not significant at p>0.25

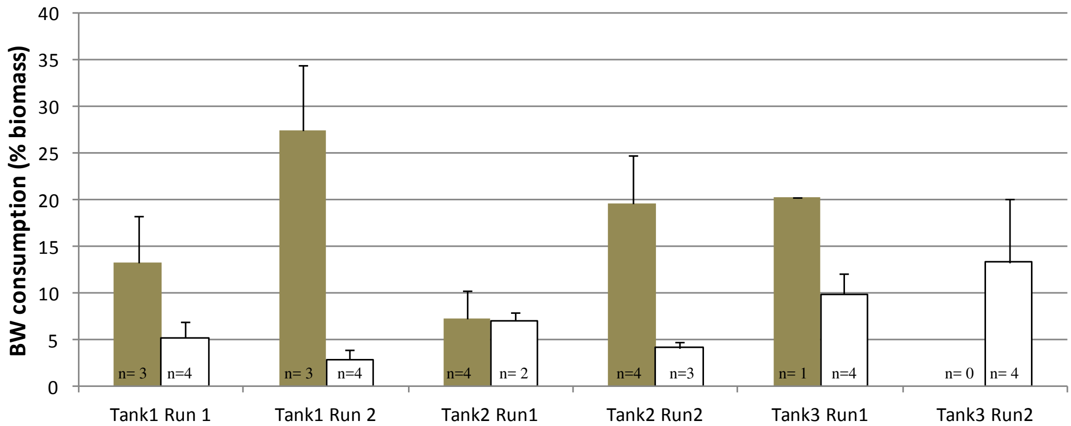


Figure 145: Proportion (mean+SE) of *P. oceanica* consumed when presented alone (grey) or together with *C. brachycarpa* (white) in each combination of Tank and Run. The numbers (n) at the bottom of each bar indicate the replicates used to calculate each mean

Table 36: Results of three way ANOVA between PO *vs.* PO-CC

Source	DF	MS	*F*	*F versus*
Tr	1	591.6315	1.77	RES[b]
Ta	2	198.8215	0.40	TaXRu
Ru	1	475.2463	0.96	TaXRu
TrXTa	2	16.0528	0.12	TrXTaXRu
TrXRu	1	163.4492	1.27	TrXTaXRu
TaXRu	2	494.6418	1.48	RES
TrXTaXRu	2	129.1396	0.39	RES
RES	22[a]	333.4173		

Cochran's test: $C = 0.459$ ($P < 0.01$)
Transformation: None

a=Degrees of Freedom corrected for missing data
b=tested over the RES MS after elimination of the TrxTa, TrxRu, TrxTaxRu terms which were not significant at p>0.25

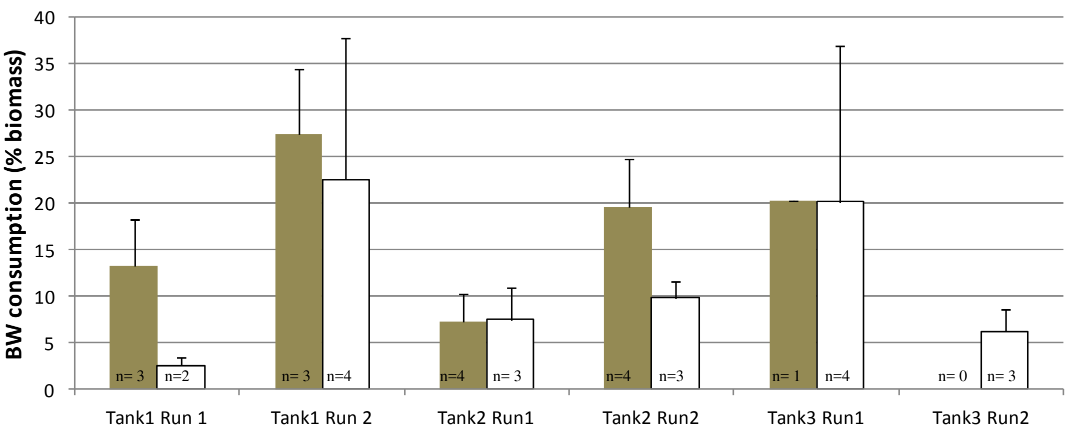


Figure 146: Proportion (mean+SE) of *P. oceanica* consumed when presented alone (grey) or together with *C. compressa* (white) in each combination of Tank and Run. The numbers (n) at the bottom of each bar indicate the replicates used to calculate each mean

Carbon and nitrogen content

The results on carbon and nitrogen contents outlined that the C:N ratio was higher in CA and CC respect to CB and PO (Figure 147). One-way ANOVA showed that there were significant differences between species (F=98.86; p<0.001); the *post hoc* test confirmed a similar molar ratio in CA and CC (60.9 ±2.5 and 55.9 ±2.5, respectively) while in CBR and PO (significant different) halved values were recorded (30.7 ±1.3 and 22.9 ±0.3, respectively).

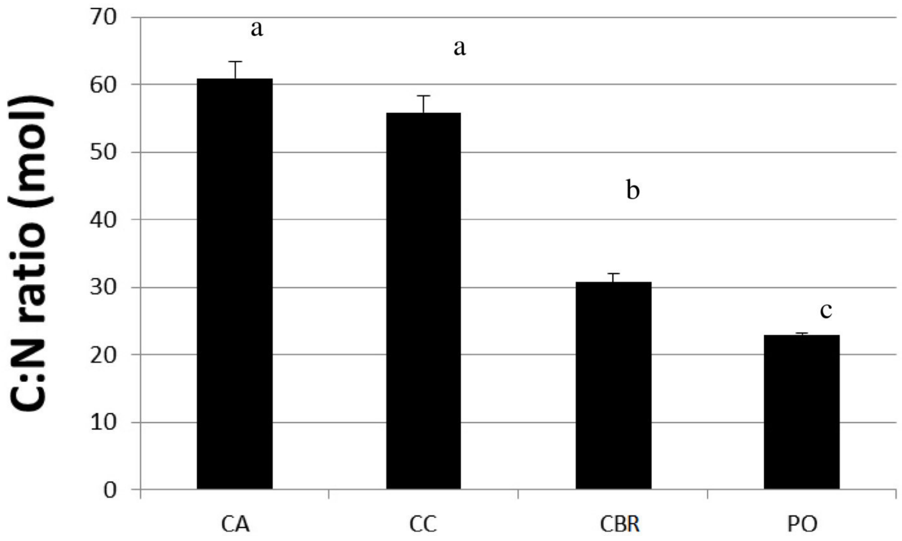


Figure 147: C:N ratio expressed as the molar ratio between the two elements (mean +SE, n=6). Different lowercase letters above bars indicate significantly different means according to *post hoc* test

Significant higher nitrogen contents in CBR and PO were found when the two elements were considered separately; in particular the values were doubled and tripled, respectively, in comparison to those obtained from the remaining two species (CA and CC) (F=251.7; $p<0.001$) (Figure 148). On the opposite, the percentage of carbon was always significant different among the four macrophytes (F= 263.9; $p<0.001$, even if with values around 28.7 (CC) and 34.2% (PO) (Figure 149).

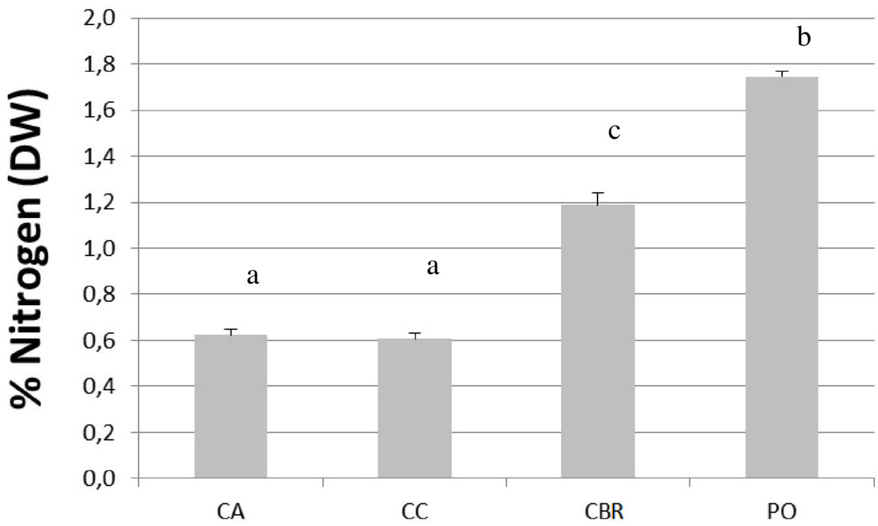


Figure 148: Percentage of Nitrogen content in the different macrophytes (mean +SE, n=6) Different lowercase letters above bars indicate significantly different means according to *post hoc* test

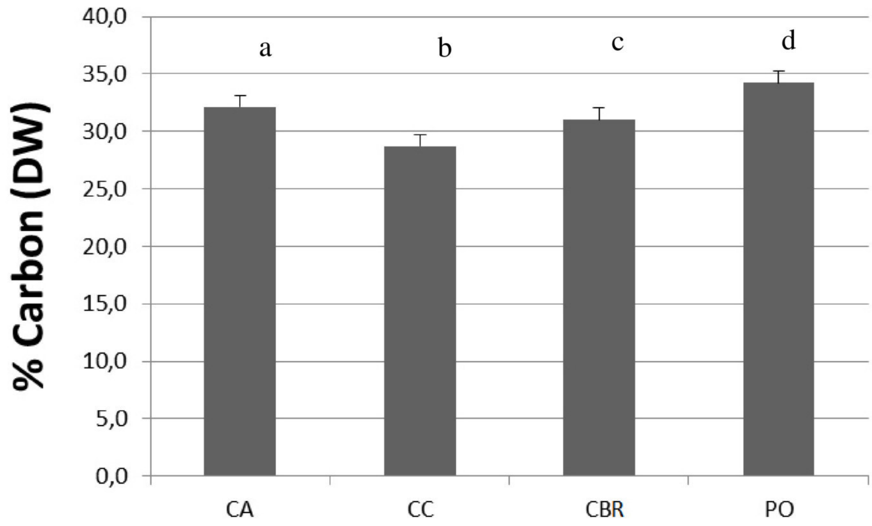


Figure 149: Percentage of Carbon content in the different macrophytes (mean +SE, n=6). Different lowercase letters above bars indicate significantly different means according to *post hoc* test

The pattern previously observed for the molar ratio of C and N has been also recorded for the phenolic content (Figure 150). Their content was the highest in shallower species (CA:13.30±0.25 mg/g-^{1}, 1.33% DW and CC:14.65±1.87 mg/g-^{1}, 1.47% DW) and progressively decreased according to the depth distribution of CBR (2.89±0.11 mg/g-^{1}, 0.28% DW) and PO (0.77±0.15 mg/g-^{1}, 0.08% DW) (Figure 150). The ANOVA and *post hoc* test revealed that all species have high significantly different ($p<0.0001$) content of phenols (F=636.2; $p<0.001$).

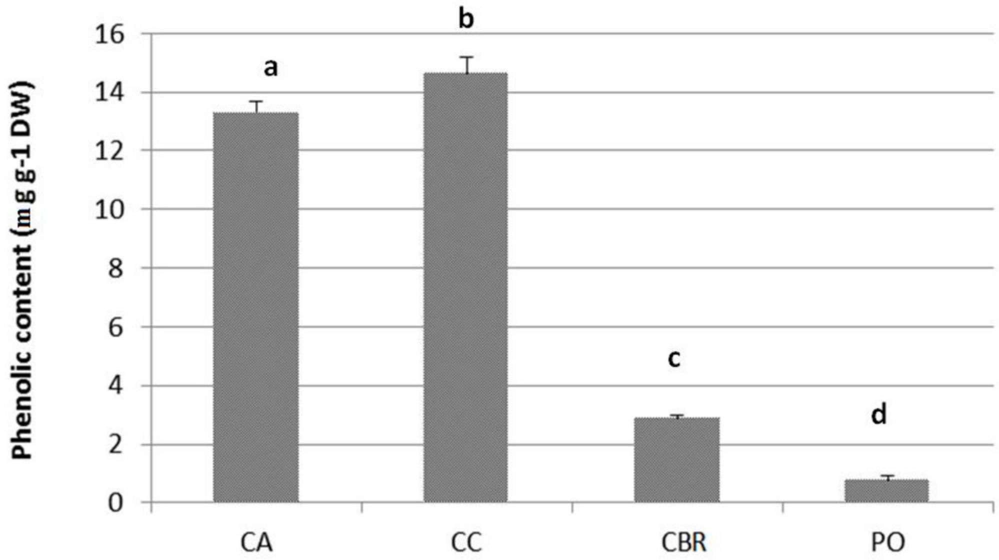


Figure 150: Total phenolic content (mean +SE, n=12) for each species. Different lowercase letters above bars indicate significantly different means according to *post hoc* test

Paired t test were performed on the phenolic content in species sampled at different time (T1 and T2, according to the different feeding experiments), in order to avoid a different production related to the sampling damage. The results (Table 37) revealed that all species have not significant content of phenolic compounds at different times ($p>0.05$).

Table 37: T test result for different species between times (T1 and T2) of collection

Species	t test ($p>0.05$)
CA_{T1} -CA_{T2}	0.1848
CBR_{T1}-CBR_{T2}	0.0712
CC_{T1}-CC_{T2}	0.3089
PO_{T1}-PO_{T2}	0.8846

6.4 Discussion

This study provides the first data on the possible feeding preferences of *Paracentrotus lividus* on *Cystoseira amentacea*, *Cystoseira brachycarpa*, *Cystoseira compressa* and *Posidonia oceanica*. For this last species, *P. lividus* is one of the three most common consumers together with the fish *Sarpa salpa* and the isopod *Idotea balthica*.

Overall, the experiment highlighted the generalist behaviour of *P. lividus*, which showed no strong preference. Urchins fed indiscriminately on different macrophytes according to the equal choice behaviour between macrophytes offered alone or together, or showed some preference behaviour, but in most cases not consistent among tanks and between experimental runs. This last result could be attributed to natural variability due to uncontrolled processes differing among tanks and/or between runs of the experiment (context-dependent effects).

The average consumption by *P. lividus* of about 67 mg (DW) per day per individual agrees with previous studies for this species (Nédélec &Verlaque, 1984; Boudoresque &Verlaque, 2001).

Differences in carbon and nitrogen content, C:N ratio and phenolic content seem not to affect the palatability of plant species. This is an interesting result considering that nitrogen content is often assumed to be positively correlated with food choice in this sea urchin (Boudoresque & Verlaque, 2001).

The only consistent (across all tanks and runs) significant result was a higher consumption of *P. oceanica* when presented alone compared to when it was presented together with *Cystoseira amentacea*. This suggests some preference of *P. lividus* for *C. amentacea* (lower nitrogen content) over *P. oceanica* (higher nitrogen content).

The present experiment does not support the hypothesis that *P. lividus* strongly selects macrophytes by preferring more palatable (in term of total phenolic or elemental contents) species, being able to actively choose them even when they are less abundant. However, other grazers, not examined here, could exert their own selection, such as the salema fish (*Sarpa salpa*) and, therefore, be responsible for different grazing impact on different macrophytes. Further experimental research on this topic is needed.

In this study, for the first time, carbon and nitrogen content of *C. amentacea* (C: 32.16±0.16; N: 0.62±0.03), *C. brachycarpa* (C: 31.01±0.11; N: 1.19±0.05) and phenolic content of *C. brachycarpa* (TPC: 2.89±0.11) were estimated. The C:N ratio, carbon and nitrogen elemental content of the four examined macrophyte species are comparable with those reported in the literature (Garcia-Sanchez et al., 2014 for *C. compressa*; Celis-Pla et al., 2014 for *C. tamariscifolia*, a species close to *C. amentacea*; Duarte, 1990 for *P. oceanica*). Vergés et al. (2009) indicated, by means of an *in situ* choice experiment, that *C. brachycarpa* (i.e. *C. balearica)* was less consumed by *S. salpa* compared to other *Cystoseira* species (*C. compressa* and *C. amentacea*). This was explained with relatively higher levels of terpenoid metabolites present in *C. brachycarpa* (Amico, 1995). However, our results do not support this hypothesis, although with the caution that the present study focused on specimens collected deeper.

Present TPC values are similar to those reported in the literature regarding *C. amentacea* (0.8% DW; Mannino et al., 2014) and C. *compressa* (0.1-0.5% DW; Ragan & Glombiza, 1986), and lower than those reported for *P. oceanica* (10-60 mg/g DW; Agostini et al., 1998). Higher values of phenols found in the two species thriving at the water mark (*Cystoseira amentacea* and *Cystoseira compressa*) are probably related to higher irradiance levels and to the photo-protection role played by these compounds (Abdala-Diaz et al., 2006), while they seem to have no effects as deterrents against *P. lividus* grazing.

However, TPC and elemental content (especially the former) can change considerably according to many factors such as season (Mannino et al., 2014) and grazing pressure (Verges et al., 2009). Further studies performed on populations of the same species, but under different ecological conditions, could assess (coupled with specifically designed manipulative experiments) the relevance of other factors for variations of TPC.

As in any mesocosm experiment, present findings must be interpreted with some cautions due to the possibility that the activity of grazers under the experimental conditions changes in comparison to that occurs in the natural environment. However, the present experiment allowed to control and maintains a number of potentially relevant environmental variables (temperature, salinity, depth, light exposure, and oxygen concentration).

Another potential caveat is that starved fauna generally feeds less discriminately than fauna that has been fed (Cronin and Hay, 1996a). For example, periods of starvation longer than the present ones have been shown to increase the likelihood of grazers consumption of food items containing chemical deterrents (Cronin & Hay, 1996b). Our starvation period of 2 days before the start of the experiment was chosen as a compromise between the 'drastic' period (two weeks) established by Agnetta et al. (2015) and ‘no starvation’ that would have prevented to exclude that the urchin individuals naturally differed at the beginning of the study in their feeding status and grazing behaviour (Rochette et al., 1994). Moreover, the size and age of sea urchins could affect their preference and response to food items. This issue should be addressed with further research combining food choice treatments involving urchin individuals of a range of sizes.

P. lividus can act as a keystone species in Mediterranean rocky assemblages (Tomas et al., 2010) due to its generalist behaviour (Verlaque, 1987), although some food items seem to be preferred (Boudoresque & Verlaque, 2001; Strong et al., 2009; Monteiro et al., 2009). According to these authors, *Cystoseira* spp. likes better than *P. oceanica*. The same pattern was clearly not shown by the present study.

An important aspect of the experimental design used here was is its ability to avoid confusion of preference from any other reasons because the consumption of each species when available alone (i.e. 'single') was also determined and compared with the consumption when offered together with another species (i.e. 'combined) (Underwood & Clarke, 2005; Cacabelos et al., 2010).

The described short-term scenario of no sea urchin preference on four different macrophytes calls for future investigations carried out over longer periods. These should span possible long-term responses affecting the grazer after the ingestion of different food items, possibly leading to changes in relevant (positively or negatively affecting the sea urchin behaviour) variables such as growth rate, reproductive fitness and genetic expression.

Further research in this field is needed to better understand the mechanisms that may shape Mediterranean rocky shores towards alternative states, i.e. barren grounds versus Fucales forests, especially focusing on more than one acting grazer, mechanisms and possibly feedbacks along trophic cascades. The consequent knowledge would critically contribute to a more complete understanding of the general decline trend of Mediterranean Fucales forests.

7. General conclusions discussions and future directions

7.1 The status of Fucales in the Gulf of Naples

This thesis offered an updated overview on past and present occurrence of Fucales in the Gulf of Naples from shallow belts to deep forests. In more than 84% of historical sites we did not find the past recorded species. On a total of 18 species (15 *Cystoseira* and 3 *Sargassum* species) only 11 species have been recorded again, persisting in few localities but with very low abundances. On this result, many of them can be considered in decline, almost extinct or very likely extinct at the gulf scale (Table 38); however they could be considered as functionally extinct in the study area.

The Gulf of Naples experienced in the last 60 years (at least) a huge anthropogenic pressure, leading to extensive impacts that re-shaped and homogenised coastal ecosystems that are

Table 38: Final status of *Cystoseira* and *Sargassum* taxa based on their occurrence reported in different periods along the study area, after the current survey (2013-2016) *= scattered populations, **⚐**= species deserving conservation priority

Taxon	**Historical records**	**2013-2016 records**	**Trend at gulf scale**	**Conservation Priority**
CA	Very common	Common*	**Local decline**	⚐
CB	Common	Absent	**Extinct**	
CBB	Very rare	Absent	**Extinct**	
CBR	Common	Very rare	**Local decline**	⚐
CC	Very common	Common	**Local decline**	⚐
CRIN	Very rare	Very rare	**Almost Extinct**	⚐
CD	Very rare	Absent	**Extinct?**	
CFF	Very common	Very rare	**Almost Extinct**	⚐
CFu	Very rare	Absent	**Extinct**	
CMe	Common	Very rare	**Local decline**	⚐
CSA	Very rare	Very rare	**Local decline**	⚐
CS	Very common	Very rare	**Local decline**	⚐
CSE	Very rare	Absent	**Extinct**	
CT	Rare	Absent	**Extinct**	
CZ	Rare	Very rare	**Local decline**	⚐
SA	Common	Very rare	**Almost Extinct**	⚐
SH	Common	Absent	**Extinct?**	
SV	Very rare	Very rare	**Stable ?**	

generally different in term of number of species, abundances and bathymetric zonation of many assemblages.

Many other species besides algae, such as the colonial scleractinian coral *Astroides calycularis*, have locally disappeared in many localities of the gulf, compared to historical records (Funk, 1927, 1955; Bacci, 1946, 1972). Even these taxa have been reported to be affected by human activities (such as coastal urbanization, marine pollution, siltation; Moreno et al., 2008); therefore these losses are further proofs of the catastrophic anthropogenic impact experienced by Neapolitan underwater seascapes.

The introduction of artificial infrastructures leads in many places to a coastal homogenization providing habitats different from the original natural ones in term of substrate three-dimensional complexity, roughness and lithology. This replacement also causes deflection of currents that changed hydrodynamic conditions; these impacts are evident in striking erosional phenomena such as the Ischia cases (Zucco, 2003). A general shift from three dimensional branched ecosystem engineers to turf forming species has been documented in most of the impacted areas, as evidenced also by existent literature (Airoldi & Beck, 2007). Recent studies demonstrated also the importance of biotic interactions in artificial habitats (Ferrario et al., 2016), probably related to a displacement of top predators in the food web; this factor needs further detailed studies.

Many common and frequent Fucales along the coastline of the gulf have disappeared and can be considered as locally extinct at local scale or reduced to relict records (mostly few specimens) in sectors more distant from Naples metropolitan area (Ischia, Capri, Vervece bank), where cumulative impacts affecting the benthic assemblages are reduced.

This thesis provided also a current georeferenced status through the Fucales Cartographic Database (FuCart DB) and all the output products (maps) that will be useful as reference line in the future implementation of the framework of Water Framework Directive (WFD) and Maritime Spatial Planning (MSP) of the entire gulf. These studies will be of great support for further ecological and molecular investigations such as those focused to study the connectivity of some species at different spatial scales. Moreover, the pilot study on nutrients and the experiment on food preference can represent the basis for a thorough research on top-down and bottom-up factors related to the decline of these species. As a result, this thesis (with a detailed cartography of Fucales abundance, coverage, continuity, and species richness) will be an important reference point for next comparisons in this area.

A final overview of the updated scenario is represented in Figure 151 where a concise statement of the destiny of historical records has been reported. As evidenced by literature, when proper reference baseline are available, temporal stability of belts and forests are extremely rare (Thibaut et al., 2014; Thibaut et al., 2016b). Natural recovery after decline of *Cystoseira* and *Sargassum* have been rarely recorded (Hanel, 2002; Orlando-Bonaca & Mavric, 2014; Ivesa et al., 2016). In the depleted zones only relict populations exist and moreover the low dispersal ability in the case of *Cystoseira* spp. (Susini, 2006), the fragmented assemblages and the habitat loss occurred represents huge limitations, leading to a lacking of suitable natural habitat in many areas.

Whatever the species considered, the natural recovery seems to be really unlikely in many of the sectors of the study area, and an optimal strategy to face the current fucoid decline must be urgently delineated and pursued. A separate discussion can be done for *Sargassum vulgare* that seems to better cope propagation issues due to the presence of aerocystis and indeed in the study area it was found to settle also in artificial barriers.

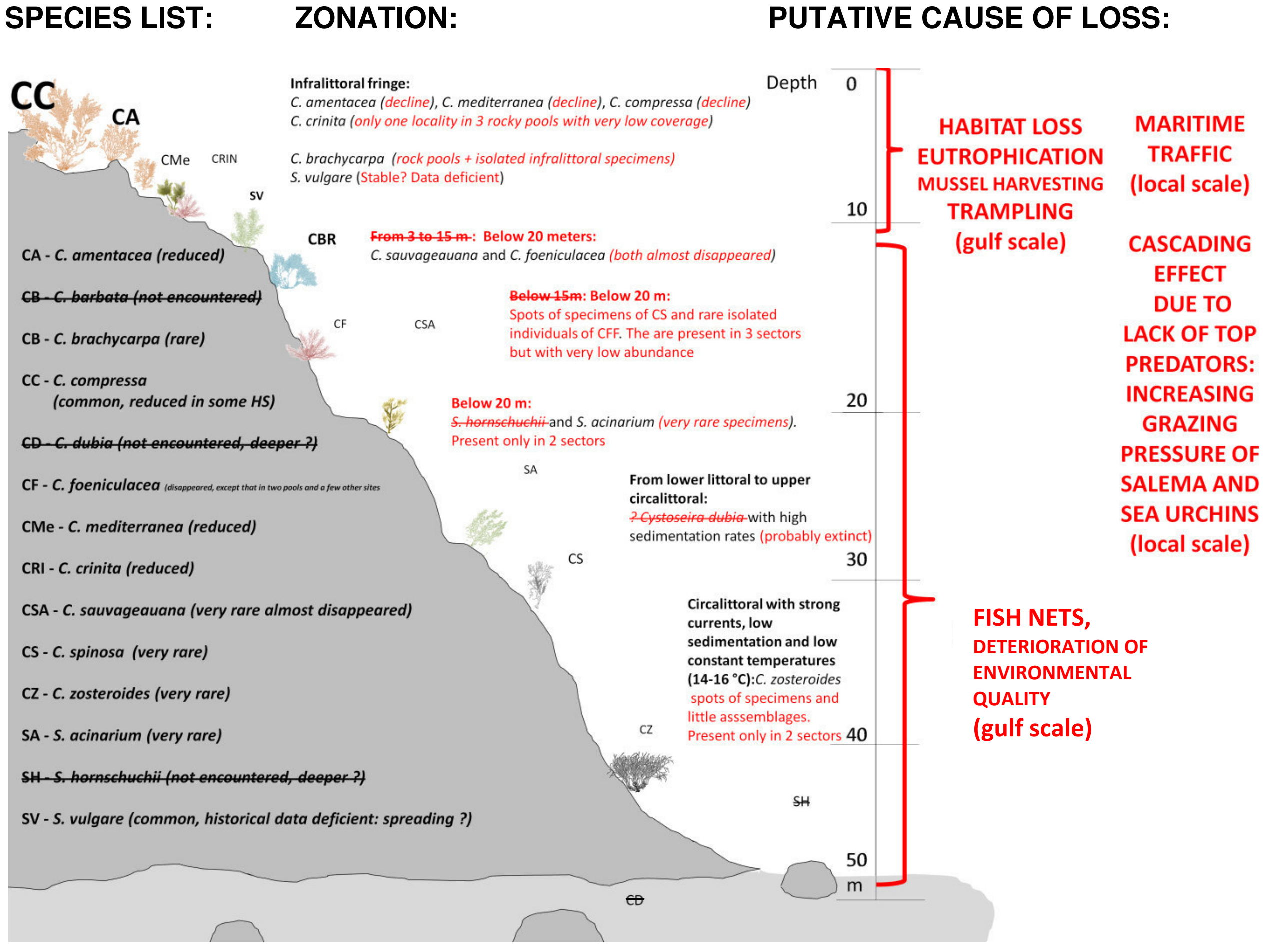


Figure 151: An overview of the updated scenario outlined by this thesis. The picture brings together most of the species historically present in the study area for illustrative needs. On the left side, list of the existing species; on the centre comments about the historical change per each species. On the right, an evaluation of the putative cause of loss. Bathymetric occurrence is shown according to Cormaci & Furnari (2012), historical and current occurrence in the study area

Transplantation of *Cystoseira* spp. (also on artificial habitats) has been suggested as an useful tool to improve the restoration of lost populations (Falace et al., 2006; Susini et al. 2007a; Perkol-Finkel & Airoldi, 2010; Gianni et al., 2013); despite current available techniques there are still many issues to be outlined and improved. Until now transplants seem to never survive and self-maintain, due to waves, human presence and grazing pressure, even when grazers were removed (Robvieux et al., 2013; Thibaut et al., 2014). These attempts, that we also tried to conduct in the gulf with a very preliminary pilot study by using the less sensitive species (*C. compressa*), are time and money consuming if first of all we do not understand the causes of local loss. Moreover, the restoration can be successful only if fully supported by a focused management policy.

The increase of anthropogenic impacts in the gulf from the beginning of 20th century is testified by the drastic decrease of brown algae and the contemporary increase of sciaphilous species such as many Rhodophyta. In particular the vacancy of the *Cystoseira* shallow belt seems to have facilitated the settlement of *Asparagopsis taxiformis*. In addition the recent and invasive colonization by allochthonous species such as *Caulerpa cylindracea* and *Womersleyella setacea* could also play a role in the decline of fucoids, as their settlement may favour the turf formation and sediment depositions thus inhibits fucoid recruitment (Ballesteros et al., 1998; Hereu et al., 2008; Ballesteros et al., 2009; Draisma et al., 2010). The analysis of chorographic spectra also seems to validate the anthropogenic disturbance, together with co-occurring changes in climatic conditions and the decreasing presence of cold affinity species (Buia et al., 2013a).

The loss of shallow historical records of fucoids in the different sectors in which the area has been divided is huge and corresponds to the intensity of the development of artificial infrastructures (Figure 152).

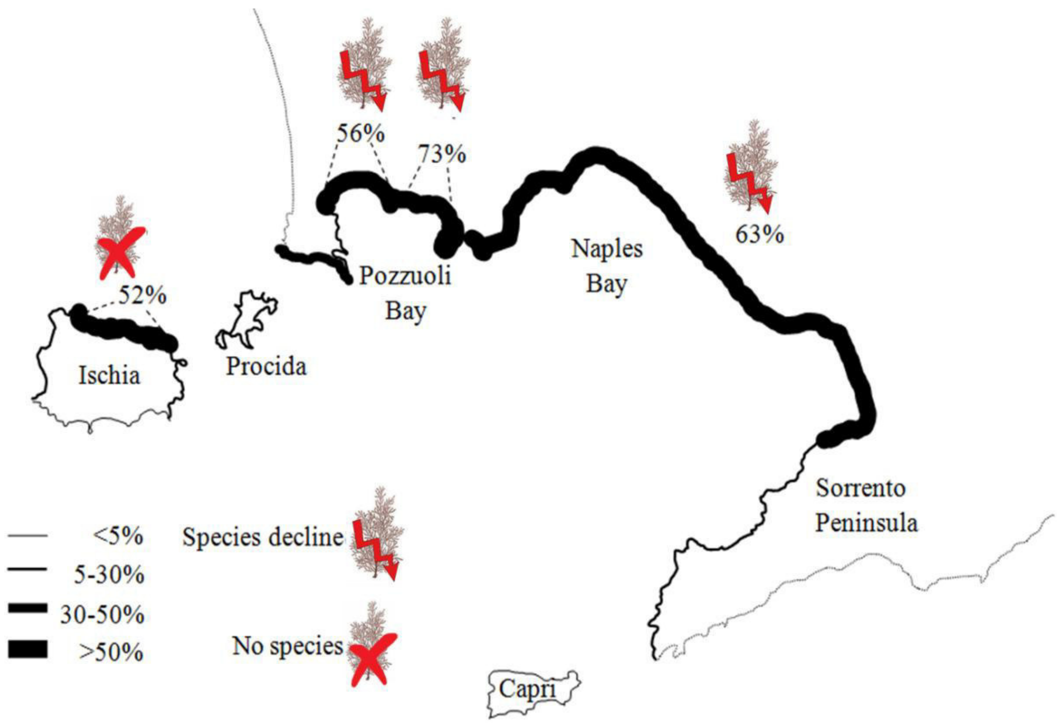


Figure 152: Percentage of coastal transformations according to the different sectors of the Gulf of Naples in which historical records have been reported and dramatic decline of shallow species has been detected (Grech et al., 2015b)

In the Bay of Naples more than half of the coast (63%) is artificial and the loss of HS here is very high. Overlapping the loss of species for different areas in the Figure 152, a comparable loss of species (71%) has been recorded in the Pozzuoli Bay (49% of coastal transformation; respectively 56% in Pozzuoli-Baia and 73% in Pozzuoli ex Italsider), where a substantial industrial settlement has developed on the eastside. In this sector Nisida was an island at the Funk surveys' time but later was linked with a bridge altering the environmental conditions of the area (currents, sedimentation and habitat fragmentation).The development of industrial plant of Italsider-Cementir further complicated the habitat integrity. Among the Phlegrean Islands, the northern side of Ischia recorded a massive urbanization (52%) (Zucco, 2003) and a huge loss of HS, HR and species (100%) has been detected.

The deep species could be extirpated by the intense historical fishing pressure and deterioration of environmental quality (Figure 151).

The lack of knowledge on very deep occurrence (below 40-50 m depth) calls for further studies: ROVs and/or projects involving technical divers will be taken into account. Results obtained in the framework of the pilot project 'Progetto Fucales: chi le ha viste?' at the gulf scale (Figure 153) could be extended at national scale with the double effect to raise awareness and fill the gap of knowledge of fucoid distribution along Italian coasts.

The lessons for future extension of this pilot project will be a wide range outreach effort and the involvement of all the stakeholders with many transversal meetings and events. The number and quality of these activities on citizen science projects indeed has a deep impact on the gathered results and the participants should be motivated to collect data, stressing the importance of the project aims as well as by a program recognizing their efforts (Van Den Berg et al., 2009; Dickinson et al., 2012).

Figure 153: Underwater photos from Sorrento and Amalfi coast, gathered thanks to Progetto Fucales Citizen Science project (photos courtesy respectively of A: Enrico Gargiulo, B: Massimiliano De Martino, C: Edoardo Ruspantini)

The evaluation of anthropogenic pressures in the gulf evidenced huge impacts but also lack of detailed data and calls for a greater collaboration between Regional authorities, Municipalities, Protected Areas and local policy providing a realistic and detailed picture of the environmental status, the more accurate as possible. This approach will lay the foundations for a holistic and interdisciplinary study ever more exhaustive in the study area, because is widely recognized that healthy ecosystems provide goods and services to human population and they are essential for social and economic reason, strongly contributing to human welfare (Costanza et al. 1997).

Integrated approaches have been recently applied on some fucoids at the SZN in order to understand physiological, biochemical and molecular responses to environmental changes (Kumar et al., 2017; Kumar et al., in press.) Finally, a phylogenetic reassessment of Mediterranean Fucales is desired. In the absence of a solid molecular phylogeny indeed, the status of these species should be necessarily reviewed at Mediterranean basin to clarify species boundaries and the possible occurrence of cryptic species, within a complex and polyphyletic group (Draisma et al., 2010; Dixon et al., 2014).

7.2 Ecological consequences of loss and conservation issue: the need of true protection

The loss of these ecosystem engineer species is absolutely worrying. A typical regime shift with the replacement of Fucales forest to less structured algal communities dominated by Sphacelariales, Dyctiotales has been observed in the study area, as well as outside the gulf (Thibaut et al., 2015a,b). Relict populations of Fucales have lost their functional role with a possible consequence on the associated assemblages and biodiversity. The economic importance of these habitats forming species being nursery for teleost species and many other organisms could be directly or indirectly relevant (Cheminee et al., 2013; Thiriet et al., 2016). The loss of a climax community can have important consequences in the colonization of these habitats by non-indigenous species.

On the base of the gathered results, at the gulf scale, the most threatened species (in order of risk) are currently *C. crinita*, *C. mediterranea* and *C. amentacea* in the upper sublittoral fringe and *C. spinosa*, *C. sauvageauana, C. foeniculacea*, *C. zosteroides*, *Sargassum acinarium*, *C. brachycarpa* in the lower sublittoral and circalittoral zone. Among them, five (*C. mediterranea*, *C. amentacea, C. spinosa*, *C. sauvageauana*, *C. brachycarpa*) are Mediterranean endemisms. Also the upper sublittoral *C. compressa,* a species that is widely considered to have high ecological plasticity because less sensitive than others (Falace & Zanelli, 2006; Ballesteros et al., 2007), experienced in the Gulf of Naples a huge historical decline, and could be included among the threated species. Unfortunately, up to now all these fucalean taxa have not yet been assessed for the IUCN Red List: 'Not Evaluated' (NE) (IUCN, 2016) but they urgently need a strong and true protection status at the Mediterranean Sea scale. The first step should be to assess their status and regression at basin scale according to defined criteria in order to include some of them in a new IUCN Red List, as recently suggested by some other authors (Thibaut et al., 2015b; Blanfuné et al., 2016)

A proposal at regional level (Mediterranean France and sub-sectors) for *C. crinita* has been reported by Blanfuné et al. (2016) but no official measures have been taken until now. Most of the species that on the basis of my results are facing an extinction are simply listed in annexes of European conventions but are not binding and as a consequence they are not protected (Barcelona Convention 1976,1995; Bern Convention 1979; Council of Europe 1979). Results that I obtained should be used to enforce this need.

According to the IUCN Red List criteria (IUCN, 2012), *C. crinita* should be classified as 'Critically Endangered' (CR) near to 'Regionally Extinct' (RE) because it is currently present in the Gulf of Naples only in 3 rock-pools in the south west of Ischia plus few scattered specimens (Sector A), while in the past it had an higher extension.

C. mediterranea suffered an historical decline of 76%, and should be considered as Vulnerable (VU) near to Endangered (EN) in the Neapolitan area, up to further (genetic) investigations will help to clearly distinguish this species from *C. amentacea*. Even this last species should be considered as Vulnerable (VU) near to Endangered (EN), because totally extinct in many coastal stretch.

C. compressa, a species that is widely considered to have high ecological plasticity because less sensitive than others (Falace & Zanelli, 2006; Ballesteros et al., 2007) could be considered near Threatened (NT).

C. spinosa was considered by Funk (1927,1955) one of the most wide spread species in the gulf up to 50 m depth. Currently, we only found isolated specimens and the most dense stands are settled along Capri only. Considering its high environmental sensitivity (Rodriguez-Prieto et al., 2013) this species should be considered as Critically Endangered (CR) at the gulf scale, being probably completely extinct all along the Sectors B and C (about 90 km of coastline).

C. sauvageauana is historically considered a very rare species as it was recorded in the gulf in the past in 5 sites only. Only a single HS was currently confirmed but the species has been found in 5 sites not previously mentioned. On these results the species should be considered as Critically Endangered (CR) at the gulf scale.

C. foeniculacea experienced an historical depletion of 96% even if it was considered very abundant by Funk (1927, 1955) The species should be considered as Critically Endangered (CR).

C. zosteroides suffered an historical depletion of 85% in the study area and is still present in 4 sites of the gulf. This species is characterized by very low grow rate making the species highly susceptible to human disturbances (Ballesteros et al., 2009; Rodriguez-Prieto et al., 2013). As a consequence, also this species can be considered Critically Endangered (EN) in the study area.

C. brachycarpa experienced a decline of 94% in historical sites, However, its occurrence (not previously reported) in dense stands only around Pietra Nera (Ischia, Sector A) makes this species the most abundant and widespread subtidal species. Very recent studies revealed that *C. brachycarpa* has a high potential of recruitment and as a consequence with a high potential to recover after disturbance (Piazzi et al., 2017). The existing forest and isolated specimens could be considered a possible relict assemblage and could testify an example of a previous large distribution of this species. In conclusion, the species should be classified as Endangered (EN).

C. barbata, a species widely distributed in the gulf both alone or mixed with *C. compressa,* was never found during this PhD work. The species should be classified as Regionally Extinct (RE).

Sargassum acinarium experienced a decline of 100% of historical sites but we currently found in 4 sites not previously mentioned. The species can be considered Endangered (EN) in the study area.

Moreover, it should be noted that some of deep species could theoretically thrive deeper than the investigated depths (even 70-100 m). Targeted ROV survey reaching about 100 meters depth are therefore encouraged to highlight the possible occurrence of deeper forests.

These considerations are, as above mentioned, an attempt to assess the local status of Fucales in the Gulf of Naples and to highlight the need to conduct a monitor programme at a larger scale (at basin scale) in order to set up a plan of conservation priorities.

This plan should comprehend a better and more integrated coastal management mainly as it concerns artificialization, urbanization, habitat fragmentation and restoration actions (i.e. Perkol-Finkel & Sella, 2014; http://www.econcretetech.com/technology/projects) in order to enhance biodiversity and ensure the best conditions for a natural or human-mediated restoration of these species.

Moreover the shallow species should be protected with the improvement of sewage treatment plant at basin and Regional scales. The deep species should be protected through the application of fishing banning inside MPAs and other areas where these species thrive.

Where dense relict assemblage of vulnerable species exist, they potentially represent the last sources of propagules (sink) for the neighbouring suitable habitats, potentially able to recolonize in the future, if suitable condition will be restored. Here strong protection measures should be developed such as avoiding human trampling (i.e. for *C. amentacea, C. crinita C. mediterranea*) in shallow protected zones and displaying panel signs dealing Fucales (Figure 154) in order to inform and preserve a future natural or human mediated reintroduction of these species.

Figure 154: Illustrative Fucales panel sign (150 x 80 cm) designed with the aim of raising public awareness to the sustainable use of the coastline without threating the still existing Fucales assemblages (Translation: You are in a protected zone; here threatened algae thrive, please: ✓don't damage them; ✓don't trample, stop or land with kayak where they thrive; ✓reach the sea with the designated access; ✓outside the forbidden zone, limit the harvesting of seafood to zones where these algae are absent (the removal of these species cause the fast colonization of other species with higher grow rate but with low environmental requirements; ✓don't sit or walk inside rock pool since these environments are considered refuge zone for these species; They thank you !!!!!!)

Concerning the deep species, fishery should be banned in the most important hotspots of biodiversity listed in this thesis (especially for those species such as *C. spinosa* and *C. zosteroides* characterized by lower growth rates), in order to preserve relict forest or sites with the highest species richness and number of total specimens. The *C. brachycarpa* forest of Pietra Nera, is not included in the zonation of Regno di Nettuno MPA (as usually occurs for marine forests in Mediterranean Sea) and strong protection measures should be applied.

Despite the low growth rate, the believed low dispersal ability, the recruitment and development of early life stages, very recent studies seem to give interesting insights on the shallower species (Piazzi et al., 2016; Thibaut et al., 2016c; Buonomo et al., 2017) and further large scale connectivity studies underlying short and long distance dispersal pattern are needed.

Thus, the best solution for the study area should be to identify the suitable populations (supported also by a genetic analysis) and act locally with large scale restoration projects by artificially increased recruitment (*in situ* seeding or *ex situ* seeding; Sales et al., 2015).

All these proposed measures and actions should be conceived, settled and promoted by research institutions and agencies involved in the framework of the Integrated Marine Policy (IMP) by the adoption of the Maritime Spatial Planning Directive (MSP, 2014/89/EU), whose main purpose is to promote the sustainable management of uses and conflicts in coastal areas through an ecosystem-based approach. This will contribute after the above mentioned actions, to reduce the impacts on sensitivity areas, in agreement with the achievement of Good Environmental Status (GES), as requested by the Marine Strategy Framework Directive (MSFD 2008/56/EC).

Therefore, the application of the proposed conservation actions should be included in the integrated Maritime Spatial Planning of the Gulf of Naples and Campania Region. However, at the current state, all the Italian condition seem to be still far behind and with an evident lack of planning and a strong fragmentation of skills and responsibilities (Country, Regions, and local authorities). This is especially true for Tyrrhenian Sea respect to the Adriatic coast (i.e. the ADRIPLAN; Barbanti et al., 2015) despite some good local insights exist (Appolloni et al., 2015; Franzese et al., 2015; Bonamano et al., 2016) and could be useful cases to improve in the future the resolution of the conflicts between coastal uses and sensitivity areas in the gulf.

Setting conservation priorities and management plans, on the other hand, generally includes the assessment of extinction risk but takes into account many other factors, as well as the probability of success of conservation actions, legal frameworks for conservation of threatened taxa, surveillance and availability of funds or personnel to carry out such actions. The latter, a very complex issue (Gill et al., 2017) in marine conservation, especially in the Italian reality where shortfalls in staff and financial resources are very common.

In the framework of this complex background, it seems quite difficult to apply conservation priorities for these species that can be effective only in a well designed and functional integrated marine policy.

7.3 Species interactions

Further researches on the causes of fucoid loss, especially considering biological interactions, represent the priority and should be pursued.

In Ischia and all along the gulf in general, sea urchin predators (mainly Sparidae and Labriadae, e.g. *Diplodus* spp.) have generally very low dimensions (15 cm) and very low densities; rare bigger specimens of *Diplodus* spp. have been recorded only in offshore and deep or protected shoals. Big size dusky groupers have been observed rarely in offshore and deep shoals (5-6 times in more than about 100 dives performed in the gulf, juveniles or young individuals are more frequent), but they never reached large size probably due to the high fishing pressure (commercial fishery and spear fishery, pers. obs.). Sea urchins are widespread along the islands in the shallowest fringe (Mulas, 2013); however no barren grounds were observed currently in the study area. Sea urchins are also harvested since many years in the study area, as this activity is considered both a common leisure activity and commercial one, and they are frequently offered in the restaurants. Unfortunately, no data on the evolution of this harvesting activity during time is available, and this is a gap that should be assessed in future research. It is possible to consider that Fucales had pulse periods of overgrazing triggered by heavy overfishing of predators and then the population of sea urchins recovered, returning to normal levels of densities with an homogeneous association of Sphacelariales. This pattern could have hidden possible past barren phenomenon, but all of these statements are only suppositions because many factors are involved and currently we do not have control sites to test these hypothesis (i.e. we don't have ancient pristine protected areas, due to the fact that marine habitats are extensively disturbed and overfished) and we don't have historical data on the abundance of grazers, differently from other sites of Mediterranean Sea (Ivesa et al., 2016).

Moreover, in the last 25 years, *Sarpa salpa* a poorly studied species in the Mediterranean Sea has attracted research interest because of its role as macro-grazer (Verlaque, 1984; Velimirov, 1984; Havelange et al., 1997; Jadot et al., 2000, 2002, 2006). There is still uncertainty about the magnitude of the mechanism but it seems to be fairly clear that these frequent schools of fish actually have no predators after the recruitment period, because no piscivores fish currently feed on them (Valls et al., 2012). Humans occasionally fish these species as by-catch in fish nets or recreational fish by fish rod in shallow areas, but they have generally a very low economic value.

Once more, there is uncertainty about the historical trend of abundance of *Sarpa salpa* in the Mediterranean, even less in the Gulf of Naples. Currently for this species no predators have been identified, despite Garrard (2013) suggested that in eastern Africa it is used as bait for large game fish such as the leerfish, *Licha amia*, and other predatory finfish, sharks and rays. The leer fish is also present to the Mediterranean area and shark, rays and other top predators such as groupers, may feed on this species, but in practice these species are not very common and the natural predation generally non reported. The IUCN (2016) database considers the populations of *Sarpa salpa* in European waters as stable, classifying it as "least concern". The species is considered by them as common and can be locally abundant. On the basis of this information on salema fish we can suppose that have increased in abundance due to cascading effects, once more because of displacement of the trophic network by top predator depletion. It is possible indeed that the overfishing of large predators in many Mediterranean areas leads to cascading effects in the food webs, but not clear information on historical abundance of salema fish in the past is available, and there are no evidences that climate change affected the abundance of these species; while there are for grazing (Garrard 2013). Interestingly however, FAO sarpa landing statistics for the Mediterranean Sea showed a steady increase over the last 50 years, with a peak in the early 1990s at around 4,000 tonnes and stabilizing at around 2,000 tonnes during the period from 1996 to 2005 (Russell et al., 2014; IUCN website). Anyhow, the overall pattern is not clear and further investigation in this topic is required.

Verges et al. (2009) showed that *Sarpa salpa* seems to be able to select more palatable species. The reasons of this choice are still far from clear and in light of our results of the sea urchin food preference, it should be more deeply investigated, since my results on the chemical analysis performed on species already considered by Verges et al. (2009) gave different results. In particular the TPC I obtained for *C. brachycarpa* were lower respect to shallower species, so further studies are needed. Recent studies (Gianni, pers. comm.) in fact seems to prove that salema activity can affect biomass and reproductive potential of *Cystoseira* forests.

In conclusion, it is possible that in the past or recent times in the study area a high abundance of grazers (sarpa, sea urchins, crustacean meso-grazers) strongly contributed to this loss, but further experiments are needed to clarify the role of these species in the Fucales depletion.

7.4 The importance of long term ecosystem research stations, effective management and social science

Long term monitoring studies are of great importance in marine ecology. Without the ecological 'masterpieces' of Funk and Valiante's studies, no current trend on macroalgae would have been possible to highlight in this thesis. Current development of user-friendly technologies will allow to further deeply investigate state of our ecosystems. GPS devices can be advantageous tools for the monitoring of marine habitats, coupled with large scale drones technology and ultra-high definition satellite images for shallow species and ROV explorations for the deep ones.

This study gave an updated overview of the status of the order Fucales in the Gulf of Naples and all the data obtained are a solid baseline for further future research in term of regression or progression after an eventual desirable recovery, at least for the shallow species. The 3 long term monitoring stations settled in Ischia, (the Scannella rock-pool, the shallow belts along the island and the *Cystoseira* forest of Pietra Nera) with the cartographic support and maps altogether with the Fucales Cartographic Database (FuCart DB), will represent a valid reference for further detailed approaches and investigations. These data will be important in the framework of a proper WFD directive application and in Marine Spatial Planning hoping for an increased connectivity among properly managed protected areas. With the hope that in the future there will be a better management of MPAs (that at present can mainly be considered as 'paper parks', with few exceptions) in the framework of a proper application of MSP, the Pietra Nera site as all the other Fucales sites, deserve special interest and protection because no real action of protection on these species has been developed until now. Ischia current MPA zonation indeed, totally excludes the Pietra Nera site, where it is confined the unique true dense Fucales forest of the entire gulf.

In the study area, the fishing pressure (performed with different techniques) seems to be very high for subtidal species. This is an important issue to point out in a region where fishing activities are historically rooted, widespread and still illegally ongoing in many areas. For the species thriving at the water mark, *Mytilus galloprovincialis* harvesting could generate high levels of disturbance all along the gulf; *Lithophaga lithophaga* harvesting produced habitat destruction through the demolition of calcareous rocks in Sorrento Peninsula and Capri, mostly between few and about 15 meters. The wished future inclusion of Fucales taxa in the IUCN Red List at Mediterranean scale, supported also by these results, could help to better manage their natural habitat and enforce their conservation by law.

Commercial fishing threatened deeper species and is quite possible that in the past also trawling activities destroyed many forests when shallower trawling was a common activity, currently at least less frequent. Despite the trawling, many other gears such as trammel, gill nets and fish pots could result as very dangerous for these species. They are considered selective and less impacting fishing gears but if they are frequently deployed and not regulated, they can have detrimental effects. Few Ischia fishermen told me to have collected *Cystoseira* spp. and *Sargassum* spp. below the 'mount of S. Pancrazio-LoFelice' and La Secca (‘Ischia bank’, La Secca, for them simply 'the shoal' being the main target for the north east fishermen) between 35 and 70 m (‘40 passi’). I showed them some of my samples and they recognized them as ‘succulents plants’ (the tophules, typical reservoir structures of deep *Cystoseira* spp.).

This fact can be worth of noting for two different concepts; probably deeper there is still something of interesting remained to protect before it is too late and that people must be involved in marine biology science. These algae and their importance should be a priority target for dissemination outreach purpose. The ‘Macroalgal World’ is something very underestimated by most of people. No aroused interest lies on macroalgal species that are generally associated by citizens as something fleshy disgusting or not deserving interest. The hosted diversity by these ecosystem engineer species should be properly evidenced with social science experiences, citizen science projects and disseminations events targeted to increase awareness from local to global scale on the species and their importance.

7.5 Final conclusions

The results obtained in the present thesis suggest that, as in other Mediterranean areas, the brown macroalgae belonging to Fucales order have suffered a huge depletion.

The development of artificial coast seem to be the most important cause of loss; other causes ascribed to be of great importance in their decline have been outlined and investigated in this work (i.e. fishery, pollution), but many other further studies are needed.

For some of these species has been reported a local extinction at the gulf or sector scale. Based on my data I can report that all the shallow species are absent from Mergellina (Naples Bay) to Vico Equense (Sorrento Peninsula); deep species are absent from Procida to Santa Croce bank (Sorrento Peninsula). For most of them a functional extinction is documented, since the ecosystem engineer role is impaired.

From a conservation and biogeografic point of view it will be extremely important to improve these type of studies in most of the Mediterranean sectors where no recent data are currently available, in order to bridge the gap between different regions. Without data on the current distribution and abundance of these species indeed, it's virtually impossible to recognize the change and justify global and effective protection measures. Italy is not an exception. Despite many herbarium collections, tradition on phycological studies, the current status of Fucales of Italian coasts in unknown and a G.I.S. based approach as the one developed in this thesis is required. In particular, for the study area will be of valuable interest to improve studies in adjacent and neighbouring coastal sectors (the Pontian Islands, Gulf of Gaeta and Circeo in the north side; the Amalfi coast and Cilento in the south side).

In conclusion, the most important management focal point and guidelines for other areas will be to gather historical data on past Fucales distribution and pressures in the study area, to map their current occurrence, properly act for a conservation effort and undertake restoration projects if the previously pressures causing impacts have been removed (Gianni et al., 2013; Gianni & Mangialajo, 2016).

In a future scenario of human pressure intensification, if no true mitigation impact and conservation action will be pursued, these species are destined to totally collapse. The data gathered in this study will be of great importance for the next development in this field of research, for the application of a proper MSP and such a baseline for future assessments.

The lesson from the Gulf of Naples, one of the most populated and impacted area of the Mediterranean Sea, must be taken into account for the next development of metropolitan areas in order to properly manage the maritime spatial planning consistently with marine threatened species.

A stronger collaboration between engineers, managers and ecologists has to be pursued (Airoldi et al., 2005, Moschella et al., 2005, Firth et al., 2013) in order to mitigate the impacts of continuous coastal landscape transformations and to preserve marine biodiversity.

Overall research suggests that the maintenance and improvement of the environmental quality of the gulf is a major issue not only for ecological and conservation purpose, but also for social welfare and economic reasons.

References

Abaza, V., Boicenco, L., Bologa, A. S., Dumitrache, C., Moldoveanu, M., Sburlea, A. & Timofte, F. (2006). Biodiversity structure from the Romanian marine area. Cercetari marine–Recherches marines, INCDM Constanta, 36, 15-29.

Abdala-Díaz, R. T., Cabello-Pasini, A., Pérez-Rodríguez, E., Alvarez, R. C. & Figueroa, F. L. (2006). Daily and seasonal variations of optimum quantum yield and phenolic compounds in *Cystoseira tamariscifolia* (Phaeophyta). Marine Biology, 148(3), 459-465.

Adamo, N., d'Alise, P., Parrella, P., D'Antonio, G., Del Gaizo, G., Onorati, G., Russo, R. & Scala, F. (2009). Relazione sullo Stato dell'Ambiente in Campania. Napoli: ARPAC.

Agardh, C. A. (1820). Species algarum rite cognitae, cum synonymis, differentiis specificis et descriptionibus succinctis. Vol. 1, part 1. Lund: Beding, [i–iv], [1]-168.

Agnetta, D., Badalamenti, F., Ceccherelli, G., Di Trapani, F., Bonaviri, C. & Gianguzza, P. (2015). Role of two co-occurring Mediterranean sea urchins in the formation of barren from *Cystoseira* canopy. Estuarine, Coastal and Shelf Science, 152, 73-77.

Agostini, S., Desjobert, J. M. & Pergent, G. (1998). Distribution of phenolic compounds in the seagrass *Posidonia oceanica*. Phytochemistry, 48(4), 611-617.

Airoldi, L., Abbiati, M., Beck, M. W., Hawkins, S. J., Jonsson, P. R., Martin, D., Moschella, P. S., Sundelof, A., Thompson, R. C. & Aberg, P. (2005). An ecological perspective on the deployment and design of low-crested and other hard coastal defence structures. Coastal Engineering, 52, 1073-1087.

Airoldi, L. & Beck, M. W. (2007). Loss, status and trends for coastal marine habitats of Europe. Pages 345-405 in R. N. Gibson, R. J. A. Atkinson, and J. D. M. Gordon, editors. Oceanography and Marine Biology, Vol 45, 345–405.

Albanese, S., Iavazzo, P., Adamo, P., Lima, A. & De Vivo, B. (2013). Assessment of the environmental conditions of the Sarno river basin (South Italy): a stream sediment approach. Environmental Geochemistry and Health, 35(3), 283-297.

Amico V. (1995). Marine brown algae of Family Cystoseiraceae: chemistry and chemotaxonomy. Phytochemistry 39: 1257–1279.

Anderson, M. J. (2001a). A new method for non-parametric multivariate analysis of variance. Austral ecology, 26(1), 32-46.

Anderson, M. J. (2001b). Permutation tests for univariate or multivariate analysis of variance and regression. Canadian journal of fisheries and aquatic sciences, 58(3), 626-639.

Andersson, S., & Kautsky, L. (1996). Copper effects on reproductive stages of Baltic Sea *Fucus vesiculosus*. Marine Biology, 125(1), 171-176.

Andreakis, N., Procaccini, G. & Kooistra, W. H. C. F. (2004). *Asparagopsis taxiformis* and *Asparagopsis armata* (Bonnemaisoniales, Rhodophyta): genetic and morphological identification of Mediterranean populations. Eur. J. Phycol. 39:273–83.

Angiolillo, M., di Lorenzo, B., Farcomeni, A., Bo, M., Bavestrello, G., Santangelo, G. & Canese, S. (2015). Distribution and assessment of marine debris in the deep Tyrrhenian Sea (NW Mediterranean Sea, Italy). Marine pollution bulletin, 92(1), 149-159.

Antolic, B., Špan A., Žuljevic A., Nikolic V., Grubelic I., Despalatovic M., Cvitkovic I. (2010). A checklist of the benthic macroalgae from the eastern Adriatic coast: II. Heterokontophyta: Phaeophyceae. Acta Adriat., 51, 9-33.

Appolloni L., Di Stefano F., Donnarumma L., Romano A., Sandulli R., Russo G.F. - Aree marine protette e pianificazione spaziale marittima: il caso della zonazione dell'AMP di Ventotene e Santo Stefano (2015). Biologia Marina Mediterranea 46° Congresso della Società Italiana di Biologia Marina Torino, 13-17 giugno 2015

Araújo, R., Barbara, I., Tibaldo, M., Berecibar, E., Tapia, P. D., Pereira, R. & Pinto, I. S. (2009). Checklist of benthic marine algae and cyanobacteria of northern Portugal. Botanica marina, 52(1), 24-46.

Araujo, R., Sousa-Pinto, I., Serrao, E.A., Aberg, P. (2012). Recovery after trampling disturbance in a canopy-forming seaweed population. Mar. Biol. 159, 697–707.

Arevalo, R., Pinedo, S. & Ballesteros, E. (2007). Changes in the composition and structure of Mediterranean rocky-shore communities following a gradient of nutrient enrichment: Descriptive study and test of proposed methods to assess water quality regarding macroalgae. Marine Pollution Bulletin, 55, 104-113.

Arienzo, M., Adamo, P., Bianco, M. R. & Violante, P. (2001). Impact of land use and urban runoff on the contamination of the Sarno river basin in southwestern Italy. Water, Air, and Soil Pollution, 131(1-4), 349-366.

Arnoux, A. & Bellan-Santini, D. (1972). Relations between the pollution of the cortiou sector by anionic detergents and modifications in populations of *Cystoseira stricta*. Tethys, 4, 583-586.

ARPAC (2007). Il monitoraggio dell' *Ostreopsis ovata* lungo il litorale della Campania.

ARPAC (2016) web site: http://www.arpacampania.it/Acquemarine/Risultati_Monitoraggi

Asnaghi, V., Chiantore, M., Bertolotto, R. M., Parravicini, V., Cattaneo-Vietti, R., Gaino, F., Moretto, P., Privitera, D. & Mangialajo, L. (2009). Implementation of the European Water Framework Directive: Natural variability associated with the CARLIT method on the rocky shores of the Ligurian Sea (Italy). Marine Ecology-an Evolutionary Perspective, 30, 505-513.

Aysel, V., Kesercioğlu, T., Güner, H. & Akçay, H. (1990). Marine algae of Trabzon. X. Ulusal Biyoloji Kongresi. 18-20 Temmuz, Erzurum. Botanik Sirküleri, II, 183-192. (In Turkish).

Azzurro E., Andaloro F. (2004). A new settled population of the Lessepsian migrant *Siganus luridus* (Pisces: Siganidae) in Linosa Island, Sicily Strait. Journal of The Marine Biological Association of the United Kingdom, 84: 819- 821.

Babbini, L., Bressan, G., Massa-Gallucci, A., Buia, M. C. & Gambi, M. C. (2006). Segnalazione di una *facies* a *maërl* (Rhodophyta, Corallinales) lungo le coste dell'Isola d'Ischia. Biologia Marina Mediterranea, 13, 548-552.

Bacci, G. (1946). Ricerche sulle biocenosi bentoniche del Golfi di Napoli. I. La Secca di Benda Palummo: Pubblicazioni della Stazione Zoologica di Napoli, 20, 158-178.

Bacci G. (1972). Aspetti biologici dei fenomeni di inquinamento del Golfo di Napoli e delle acque adiacenti. Atti convegno parlamentare italo-franco-monegasco sull'inquinamento del Mar Tirreno. Roma, 10-11IV.1972 relazione e documenti rpeparatori. Servizio studi legislazione e inchieste parlamentari, pag. 135-137.

Baggini, C., Salomidi, M., Voutsinas, E., Bray, L., Krasakopoulou, E., & Hall-Spencer, J. M. (2014). Seasonality Affects Macroalgal Community Response to Increases in pCO_2. PloS one, 9(9), e106520.

Ballesteros, E. (1990). Structure and dynamics of the *Cystoseira caespitose* Sauvageau (Fucales, Phaeophyceae) community in the Northwest Mediterranean. Scientia Marina, 54, 155-168.

Ballesteros, E. (1991). Structure and dynamics of north-western Mediterranean marine communities: a conceptual model. Oecologia Aquatica, 10, 223–242.

Ballesteros, E., Sala, E., Garrabou, J. & Zabala, M. (1998). Community structure and frond size distribution of a deep water stand of *Cystoseira spinosa* (Phaeophyta) in the northwestern Mediterranean. European Journal of Phycology, 33, 121-128.

Ballesteros, E. (2006). Mediterranean Coralligenous Assemblages: A synthesis of present knowledge. Oceanography and Marine Biology: An Annual Review, 44, 123-195.

Ballesteros, E., Torras, X., Pinedo, S., Garcia, M., Mangialajo, L. & De Torres, M. (2007). A new methodology based on littoral community cartography dominated by macroalgae for the implementation of the European Water Framework Directive. Marine Pollution Bulletin, *55*(1), 172-180.

Ballesteros, E., Garrabou, J., Hereu, B., Zabala, M., Cebrian, E. & Sala, E. (2009). Deep-water stands of *Cystoseira zosteroides* C. Agardh (Fucales, Ochrophyta) in the Northwestern Mediterranean: Insights into assemblage structure and population dynamics. Estuarine Coastal and Shelf Science, 82, 477-484.

Ballesteros, E., García, M., Torras, X., Weitzmann, B., Pinedo, S., Jordana, E. & Satta, M.P. (2011). Informe anual del programa CTN1001835 "Disseny realització i suport del programa de vigilància de la qualitat de les aigües litorals de Catalunya, en funció de les comunitats de macroalgues, segons la directiva Marc de l'Aigua i de la prevenció de la implantació d'espècies invasores". Any 2011. Agència Catalana de l'Aigua. Departament de Medi Ambient i Habitatge. Generalitat de Catalunya.

Balsamo, F. (1892). Manipolo di alghe napolitane Bollettino della Società dei Naturalisti in Napoli, ser I, 6(1), 77-97

Balzano, R., Vetrano, G., Di Stefano, F., Di Maio, G., & Carrada, G. C. (2005). Dati Preliminari Sul Popolamento Ittico Dello Scoglio Del Vervece (Area Marina Protetta Di Punta Campanella, Tirreno Meridionale). Biologia Marina Mediterranea, 12 (1), 127-129.

Barbanti, A., Campostrini, P., Musco, F., Sarretta, A., and Gissi, E. (2015). Developing a Maritime Spatial Plan for the Adriatic Ionian Region. CNR-ISMAR, Venice, IT.

Barcelona Convention, (1976). Convention for the protection of the Mediterranean Sea against pollution. 16 February 1976. http://www.unepmap.org. Accessed November 6, 2015.

Barcelona Convention, (1995). Convention for the protection of the marine environment and the coastal region of the Mediterranean. 10 June 1995. http://www.unepmap.org. Accessed November 6, 2015.

Barreiro, F., Gómez, M., Lastra, M., López, J., & De la Huz, R. (2011). Annual cycle of wrack supply to sandy beaches: effect of the physical environment. Marine Ecology Progress Series, 433, 65-74.

Bavestrello, G., Bo, M., Canese, S., Sandulli, R. & Cattaneo-Vietti, R. (2014). The red coral populations of the gulfs of Naples and Salerno: human impact and deep mass mortalities. Italian Journal of Zoology, 81(4), 552-563.

Bedini R., Bonechi, L. & Piazzi, L. (2011). Mobile epifauna associated to *Cystoseira* spp. 42° Congresso della Società Italiana di Biologia Marina.

Bellan-Santini, D. (1963). Etude quantitative du peuplement à *Cystoseira stricta* (Montagne) Sauvageau. Rapport et Procès Verbal de la réunion de la Commission Internationale des Explorations scientifiques en Mer Méditerranée, 17, 133–138.

Bellan-Santini, D. (1964). Influence de la pollution sur quelques peuplements superficiels de substrat rocheux. In: CIESMM, Symposium sur la Pollution Marine par les Microorganismes et les Produits Pétroliers, Monaco, pp. 127–131.Bellan-Santini, D. & Desrosiers, G. (1977). Distribution du benthos de substrat dur dans un golfe soumis a` de multiples pollutions (golfe de Fos). IIIe`mes Journe´es Etudes Pollutions, Split, CIESM, 153–157.

Bellan, G. & Bellan-Santini, D. (1972). Influence de la pollution sur les peuplements marins de la region de Marseille, Mediterrannee nord-orientale. In: Pollution and Sea Life Fishing News (Books).

Bellan-Santini, D. & G. Desrosiers, (1977). Distribution du benthos de substrat dur dans un golfe soumis a de multiples pollutions (Golfe de Fos). IIIemes Journe´es Etudes Pollutions, Split, CIESM, 153–157.

Bellan-Santini, D., Bellan, G., Bitar, G., Harmelin, J.G. & Pergent, M. (2002). Handbook for interpreting types of marine habitat for the selection of sites to be included in the national inventories of natural sites of conservation interest. Tunis, UNEP-MAP RAC/SPA, 217 pp.

Bellissimo, G., Lluch, J. R., Tomasello, A. & Calvo, S. (2014). The community of *Cystoseira brachycarpa* J. Agardh emend. Giaccone (Fucales, Phaeophyceae) in a shallow hydrothermal vent area of the Aeolian Islands (Tyrrhenian Sea, Italy). Plant Biosystems, 148, 21-26.

Benedetti-Cecchi, L., Pannacciulli, F., Bulleri, F., Moschella, P. S., Airoldi, L., Relini, G. & Cinelli, F. (2001). Predicting the consequences of anthropogenic disturbance: large-scale effects of loss of canopy algae on rocky shores. Marine Ecology Progress Series, 137-150.

Benedetti-Cecchi, L., Tamburello, L., Bulleri, F., Maggi, E., Gennusa, V. & Miller, M. (2012). Linking patterns and processes across scales: the application of scale-transition theory to algal dynamics on rocky shores. Journal of Experimental Biology, 215(6), 977-985.

Berger, R., Bergström, L., Granéli, E. & Kautsky, L. (2004). How does eutrophication affect different life stages of *Fucus vesiculosus* in the Baltic Sea?–a conceptual model. Hydrobiologia, 514(1-3), 243-248.

Bermejo, R., de la Fuente, G., Vergara, J. J. & Hernández, I. (2013). Application of the CARLIT index along a biogeographical gradient in the Alboran Sea (European Coast). Marine pollution bulletin, 72(1), 107-118.

Bern Convention (1979). Convention on the conservation of European wildlife and natural habitats. Strasbourg, Council of Europe, European Treaty Series, 104.

Berov, D., Ballesteros, E., Sales, M., & Verlaque, M. (2015). Reinstatement of species rank for *Cystoseira bosphorica* Sauvageau (Sargassaceae, Phaeophyceae). Cryptogamie, Algologie, 36(1), 65-80.

Berthold, G. (1882). Uber die Verteilung der Algen im Golf von Neapel nebst einem Verzeichnis der bisher daselbst beobachteten. Mittheilungen aus der Zoologischen Station zu Neapel, 3, 395-536.

Bertini, A., Nicoletti, D., Russo, G. F. & Vitolo, T. (2015). Aree protette in italia. Il caso della Campania, Rubettino editore, 315 pp.

Bevilacqua, S., Terlizzi, A., Fraschetti, S., Russo, G. F. & Boero, F. (2006). Mitigating human disturbance: can protection influence trajectories of recovery in benthic assemblages?. Journal of Animal Ecology, 75, 908–920.

Bianchi, C. N., Corsini-Foka, M., Morri, C. & Zenetos, A. (2014). Thirty years after-dramatic change in the coastal marine habitats of Kos Island (Greece), 1981-2013. Mediterranean Marine Science, 15(3), 482-497.

Birkett, D. A., Maggs, C. A., Dring, M. J. & Boaden, P. J. S. (1998). Infralittoral reef biotopes with kelp species: an overview of dynamic and sensitivity characteristics for conservation management of marine SACs. Natura 2000 report prepared by Scottish Association of Marine Science (SAMS) for the UK Marine SACs Project.

Blanfuné, A., Boudouresque, C. F., Verlaque, M. & Thibaut, T. (2016). The fate of *Cystoseira crinita*, a forest-forming Fucale (Phaeophyceae, Stramenopiles), in France (North Western Mediterranean Sea). Estuarine, Coastal and Shelf Science, 181, 196-208.

Bo, M., Bava, S., Canese, S., Angiolillo, M., Cattaneo-Vietti, R. & Bavestrello, G. (2014). Fishing impact on deep Mediterranean rocky habitats as revealed by ROV investigation. Biological Conservation, 171, 167-176.

Bokn, T. & Lein, T. E. (1978). Long term changes in fucoid association of the inner Oslofjord, Norway. Norwegian Journal of Botany, 25(1), 9-14.

Bonaca, M. O. & Lipej, L. (2005). Factors affecting habitat occupancy of fish assemblage in the Gulf of Trieste (Northern Adriatic Sea). Marine Ecology, 26(1), 42-53.

Bonamano, S., Piermattei, V., Madonia, A., Paladini de Mendoza, F., Pierattini, A., Martellucci,. Stefanì, R. C, Zappalà, G., Caruso, G., Marcelli, M. (2016). The Civitavecchia Coastal Environment Monitoring System (C-CEMS): a new tool to analyze the conflicts between coastal pressures and sensitivity areas. Ocean Science, 12(1), 87-100.

Boudouresque, C. F. (1970). Recherches de binomie analytique, structurale et expérimentale sur les peuplements benthiques sciaphilies de Méditerranée occidentale (fraction algale). La soustraite sciaphile des peuplements des grandes Cystoseira de mode battu. Bulletin - Museum National d'Historie Naturelle Marseille, 31, 141-151.

Boudouresque C.F., Cinelli F., (1971). Le peuplement algal des biotopes sciaphiles superficiels de mode battu de l'Ile d'Ischia (Golfe de Naples, Italie) Tires-à-part des Pubbl. Staz. Zool. Napoli 39 : 1-43.

Boudouresque, C. F., & Passelaigue, F. (1972). Note préliminaire sur le peuplement algal des biotopes sciaphiles superficiels battus de substrat rocheux dans la région de Marseille. Bull. Mus. Hist. nat. Marseille, 32, 125.

Boudouresque, C. F., Meinesz, A., Ballesteros, E., Ben Maiz, N., Boisset, F., Cinelli, F., Cirik, S., Cormaci, M., Jeudy de Grissac, A., Laborel, J., Lanfranco, E., Lundberg, B., Mayhoub, H., Panayotidis, P., Semroud, R., Sinnasamy, J.M. & Span, A. (1990). Livre Rouge ‘‘Gérard Vuignier’’ des végétaux, peuplements et paysages marins menacés de Méditerranée. MAP Technical Report Series 43. UNEP/IUCN/GIS Posidonie, Athens, 245 pp.

Boudouresque, C. F. & Verlaque, M. (2001). Ecology of *Paracentrotus lividus*. In: Lawrence JM (ed) Edible sea urchins: biology and ecology, vol 32. Elsevier, Amsterdam, pp 177–216.

Boudouresque, C. F. (2004). Marine biodiversity in the Mediterranean: status of species, populations and communities. Scientific Reports of Port-Cros National Park, 20, 97-146.

Bouduresque, C. F., Ruitton, S. & Verlaque, M. (2006). Anthropogenic impacts on marine vegetation in the Mediterranean. Proceedings of the second Mediterranean symposium on marine vegetation. Athens, 12-13 December 2003. United Nations Environment Programme, Mediterranean Action Plan and Regional Activity Centre for Specially Protected Areas publ., Tunis: 34-54.

Bouduresque, C. F., Bernard, G., Pergent, G., Shili, A. & Verlaque, M. (2009). Regression of Mediterranean seagrasses caused by natural processes and anthropogenic disturbances and stress: a critical review. Botanica Marina, 52, 395-418.

Buia, M. C. & Mazzella, L. (1991). Reproductive phenology of the Mediterranean seagrasses *Posidonia oceanica* (L.) Delile, *Cymodocea nodosa* (Ucria) Aschers., and *Zostera noltii* Hornem. Aquatic Botany, 40(4), 343-362.

Buia, M. C. & Groeben, C. (1999). Georg Funk (1886-1958) and the Stazione Zoologica of Naples, In (Abdelahad, N. Ed.) The Italian phycological patrimony, Gruppo di lavoro per l’Algologia della Scietà Botanica Italiana, Montecatini Terme, 8-11.

Buia, M. C., Gambi, M. C. & Zupo, V. (2000). Structure and functioning of Mediterranean seagrass ecosystems: an overview. Biologia Marina Mediterranea, 7(2), 167-190.Buia, M. C., Gambi, M. C. & Dappiano, M. (2003). La distribuzione dell'alga alloctona *Caulerpa racemosa* Forsskål) J.Agardh (Chlorophyceae) nelle isole flegree. In: Liguori, G. (Ed.), Ambiente marino costiero e territorio delle isole flegree (Ischia Procida Vivara-Golfo di Napoli). Risultati di uno studio multidisciplinare, pp. 201-211.

Buia, M.C., Gambi, M.C., Lorenti, M., Dappiano, M., Zupo, V. (2003a). Aggiornamento sulla distribuzione e sullo stato ambientale dei sistemi a fanerogame marine (*Posidonia oceanica* e *Cymodocea nodosa*) delle isole Flegree. In: Gambi, M.C., De Lauro, M., Jannuzzi, F. (Eds.), Ambiente marino costiero e territorio delle isole Flegree (Ischia Procida Vivara – Golfo di Napoli). Risultati di uno studio multidisciplinare. Società Nazionale di Scienze, Lettere e Arti in Napoli, Napoli, pp. 163- 186.

Buia, M.C., Gambi, M.C., Dappiano, M. (2003b). La distribuzione dell'alga alloctona *Caulerpa racemosa* (Forsskål) J. Agardh (chlorophyceae) nelle isole flegree. In: Gambi, M.C., De Lauro, M., Jannuzzi, F. (Eds.), Ambiente marino costiero e territorio delle isole Flegree (Ischia Procida Vivara – Golfo di Napoli). Risultati di uno studio multidisciplinare.

Buia, M. C. (2005). Results of the 'Aliens' project. Data Report.

Buia, M. C., Porzio, L. & Patti, F.P. (2007). The application of the "Carlit Method" to assess the ecological status of coastal waters in the Gulf of Naples. Proceeding 3rd Mediterranean Symposium on Marine vegetation, Marseille 27-29 March 2007, C Pergent-Martini, S. El Asmi, C. Le Ravallec edits, RAC/SPA publ., Tunis: 253-254.

Buia, M. C., Chiarore, A., Mulas, M. & Porzio, L. (2013a). Historical changes in algal diversity in the Gulf of Naples. In: Ozhan, E. (Editor), 2013. "Proceedings of the Global Congress on ICM: Lessons Learned to Address New Challenges", EMECS 10 – MEDCOAST 2013 Joint Conference, 30 Oct – 03 Nov, Marmais, Turkey, MEDCOAST Mediterranean Coastal Foundation, Dalyan Mugla, Turkey, vol 2, pp.837-846.

Buia, M.C. (2013b). Analisi bibliografica sugli impatti naturali e antropici nel Golfo di Napoli, Ritmare Report.

Bulleri, F., Benedetti-Cecchi, L., Acunto, S., Cinelli, F. & Hawkins, S. J. (2002). The influence of canopy algae on vertical patterns of distribution of low-shore assemblages on rocky coasts in the northwest Mediterranean. Journal of Experimental Marine Biology and Ecology, 267,89-106.

Bulleri, F. & Chapman, M. G. (2010). The introduction of coastal infrastructure as a driver of change in marine environments. Journal of Applied Ecology, 47, 26-35.

Bulleri, F., Bruno, J. F., Silliman, B. R. & Stachowicz, J. J. (2016). Facilitation and the niche: implications for coexistence, range shifts and ecosystem functioning. Functional Ecology, 30(1), 70-78.

Buonomo, R., Assis, J., Fernandes, F., Engelen, A. H., Airoldi, L., & Serrão, E. A. (2017). Habitat continuity and stepping-stone oceanographic distances explain population genetic connectivity of the brown alga *Cystoseira amentacea*. Molecular Ecology, 26(3), 766-780.

Bussotti, S., Buia, M. C., Di Capua, I., Gambi, M. C., Lorenti, M., Terlizzi A., Scipione, M. B. & Zupo V. (1999). Preliminary biocoenotic characterization of the protected area 'Banco Santa Croce' (Gulf of Naples, Italy). Biologia Marina Mediterranea. Genova, 6(1), 133-135.

Cacabelos, E., Olabarria, C., Incera, M., & Troncoso, J. S. (2010). Do grazers prefer invasive seaweeds?. Journal of Experimental Marine Biology and Ecology, 393(1), 182-187.

Campbell, A. H., Marzinelli, E. M., Vergés, A., Coleman, M. A. & Steinberg, P. D. (2014). Towards restoration of missing underwater forests. PloS One, 9(1), e84106.

Callahan, J. T. (1984). Long-term ecological research. BioScience, 34(6), 363-367.

Capdevila, P., Linares, C., Aspillaga, E., Navarro, L., Kersting, D. K. & Hereu, B. (2015). Recruitment patterns in the Mediterranean deep-water alga *Cystoseira zosteroides*. Marine Biology, 162(6), 1165-1174.

Capdevila, P., Hereu, B., Riera, J. L. & Linares, C. (2016). Unravelling the natural dynamics and resilience patterns of underwater Mediterranean forests: insights from the demography of the brown alga *Cystoseira zosteroides*. Journal of Ecology. This article has been accepted for publication and undergone full peer review but has notbeen through the copyediting, typesetting, pagination and proofreading process, which maylead to differences between this version and the Version of Record. doi: 10.1111/1365-2745.12625

Carbonara, P., Casciaro, L., Gabriele, R., Gaudio, P., Bitetto, I., Zupa, W., Palmisano, M. & Facchini, M. T. (2014). Deep-Water Red Shrimps Fisheries By Set Nets In The Ischia Island (Central Southern Tyrrhenian Sea) 45° Congresso della Società Italiana di Biologia Marina Venezia, 19-23 maggio 2014.

Carillo, C. (2008). SIT sulla mitilicoltura in Campania: analisi e prospettive. PhD Thesis Università Degli Studi Di Napoli "Federico II"

Carrada, G. C., Cinelli, F., Troncone, M. R. & Saggiomo, V. (1974). Contributo alla valutazione dei fenomeni di inquinamento nel Golfo di Napoli. Fondazione Politecnica per il Mezzogiorno d'Italia. Quaderno n. 92 1-16.

Carrada, G. C., Hopkins, T. S., Bonaduce, G., Ianora, A., Marino, D., Modigh, M. & Scotto, C. B. (1980). Variability in the hydrographic and biological features of the Gulf of Naples. Marine Ecology, 1(2), 105-120.

Casazza, G., Silvestri, C. & Spada, E. (2003). Classification of coastal waters according to the new Italian Water legislation and comparison with the European Water Directive. Journal Coastal Conservation, 9, 65–72.

Casola E., Magnifico G., Lanera P., Sabatella R., Santulli A., Sassu N., Fresi E. (2004). Rilevamento e caratterizzazione della flotta peschereccia che opera in Aree Marine Protette. Biol. Mar. Medit., 11 (2): 12-20.

Casu D., Ceccherelli G., Sechi N. (2006). Different structure of assemblages understoried by three Cystoseira species occurring on the same upper-infralittoral platforms. 16th Meeting of the Italian Society of Ecology.

Catra M., Grimaldi S. (2003). Una collezione di riferimento per la diversità vegetale marina del Mediterraneo: l'Erbario Giaccone, Quad. Bot. Ambientale Appl. 14 (2003), pp. 3–79.

Cecere, E., Cormaci, M., Furnari, G., Petrocelli, A., Saracino, O. & Serio, D. (1996). Benthic algal flora of Cheradi Islands (Gulf of Taranto, Mediterranean Sea). Nova Hedwigia, 62 (1), 191–214.

Cecere, E., Fanelli, G., Petrocelli, A. & Saracino, O. D. (2001). Changes in seaweed biodiversity of the Gargano coast (Adriatic Sea, Mediterranean Sea). In Mediterranean Ecosystems: Structure and Processes, F.M. Faranda, L. Guglielmo, and G. Spezie, eds., Springer Verlag Italia, Milan, pp. 347–352.

Cecere, E., Portacci, G. & Petrocelli, A. (2014). Finding of the *Codium fragile* subsp. *fragile* (Chlorophyta, Bryopsidales) alien seaweed in the Miseno Lake transitional water system (Southern Italy): an update of its distribution in Italy and in the Mediterranean Sea. Biologia Marina Mediterrarea, 21 (1): 77-80.

Celan, M., Bavaru, A. & Bologa, A. S. (1979). Cercet. mar. - Rech. mar., 12, 121-128.

Celis-Plá, P. S., Korbee, N., Gómez-Garreta, A. & Figueroa, F. L. (2014). Seasonal photoacclimation patterns in the intertidal macroalga *Cystoseira tamariscifolia* (Ochrophyta). Scientia Marina, 78(3), 377-388.

Cervera, G. G. (1955).Questa è Ischia. Amodio.

Chapman, M. G. & Bulleri, F. (2003). Intertidal seawalls new features of landscape in intertidal environments. Landscape and Urban Planning, 62, 159-172.

Chemello, R. & Milazzo, M. (2002). Effect of algal architecture on associated fauna: some evidence from phytal molluscs. Marine Biology, 140,981-990.

Cheminee, A., Sala, E., Pastor, J., Bodilis, P., Thiriet, P., Mangialajo, L., Cottalorda, J. M. & Francour, P. (2013). Nursery value of *Cystoseira* forests for Mediterranean rocky reef fishes. Journal of Experimental Marine Biology and Ecology, 442, 70-79.

Chiarore, A, Patti F.P. & Buia, M.C. (2012). Morphological and genetic variability of *Sargassum vulgare*. Pilot study of a population in the acidified zone of the“Castello Aragonese” (Ischia island, Gulf of Naples). Biologia Marina Mediterranea, 19(1), 57-58.

Chiarore, A. & Patti, F. P. (2013). Molluschi associati all’alga bruna *Sargassum vulgare* (C. Agardh, 1820) (Fucales, Sargassaceae) rinvenuti lungo le coste dell’isola d’Ischia (Napoli): check-list preliminare. Notiziario SIM, 31(2), 10-11.

Chiarore, A., Buia, M.C. & Patti, F.P. (2015). Genetic variability of *Sargassum vulgare* populations off Ischia island: the case of the acidified area ‘Castello Aragonese’. Aquatic Sciences of Limnology and Ocenography (ASLO) Meeting: Global and regional persepctives – north meets south, February 22-27, 2015 Granada, Spain.

Christie, H., Fredriksen, S. & Rinde, E. (1998). Regrowth of kelp and colonization of epiphyte and fauna community after kelp trawling at the coast of Norway. Hydrobiologia, 375/376, 49–58.

Cigliano, M., Di Stefano, F., Di Donato, R., Russo, G. F. & Gambi, M. C. (2009). Marine S.C.I in Campania: state of the art and future perspectives. Biologia Marina Mediterranea 16(1), 73-74.

Cinelli, F. (1969). Alcuni aspetti della vegetazione algale profonda del versante Sud dell' Isola d'Ischia. Giornale Botanico Italiano, 103 (6), 603-604.

Cinelli, F. (1971). Alghe bentoniche di profondità raccolte alla Punta S. Pancrazio nell'isola di Ischia. (Golfo di Napoli). Giornale Botanico Italiano, 105, 207-236.

Cinelli, F., Fresi, E. & Mazzella, L. (1976a). Ricerche sui popolamenti bentonici di substrato duro del Porto di Ischia. Infralitorale fotofilo (Macrofite e Isopodi liberi). Arch. Oceanogr. Limnol. 18 suppl. 3, 169-188.

Cinelli, F., Fresi, E. & Mazzella, L. (1976b). Studio ambientale relativo all'istituzione di un parco marino sperimentale nelle acque circostanti l'isola di Vivara. Ischia, maggio 1976 (unpublished report).

Cinelli F., Boudouresque C.F., Fresi E., Marcot J., Mazzella L. (1977a). L'aire minima du phytobenthos dans le Port de Sant'Angelo (Ischia, Italie). Rapp. Comm. Int. Mer Mèdit., 4: 148-152.

Cinelli, F., Fresi, E., Idato, E., & Mazzella, L. (1977b). L'aire minima du phytobenthos dans un peuplement à *Cystoseira mediterranea* de l'île d'Ischia (Golfe de Naples). Rapp. Comm. Int. Mer Médit, 24(4), 113-115.

Cinelli F., Boudouresque C.F., Marcot J., Mazzella L., (1977c). Note preliminaire sur les "Fonds a Peyssonnelia libres" du Golfe de Naples: Peyssonneliaceae et Cotariniaceae. Rapp. Comm. int. Mer Medit., 24 : 4.

Cinelli F., Boudouresque C-F., Mazzella L., Richard M., (1977d). Alghe marine rare o nuove per la flora italica Quad. Lab. Tecnol. Pesca, 3 (1 suppl.): 467-480.

Cinelli, F., Fresi, E., Mazzella, L. & Ponticelli, M. P. (1979). Deep algal vegetation of the western Mediterranean. Giornale Botanico Italiano, 113, 173-188.

Clarisse, S. (1980). Contribution à la connaissance de la phénologie de l'autoécologie et de l'épiphytisme de *Cystoseira balearica* Sauvageau en Baie de la Revellata (Calvi, Corse). Mémoire de Licence. Université de Liège, 77 p.

Clarisse, S. (1984). Apport de différentes techniques cartographiques à la connaissance de l'autoécologie de *Cystoseira balearica* Sauvageau, macroalgue marine dominante dans la région de Calvi (Corse). Lejeunia, 113, 1–24.

Claudet, J. & Fraschetti, S. (2010). Human-driven impacts on marine habitats: a regional meta-analysis in the Mediterranean Sea. Biological Conservation, 143, 2195-2206.

Cognetti, G. & Santarelli, M., (1960). Ricerche sulle zoocenosi bentoniche del Golfo di Napoli II. La cosiddetta secca di San Giovanni a Teduccio. Bollettino di Pesca Piscicoltura e Idrobiologia. 1959, 35 (N.S. 14 1), 10-20.

Colantoni P., Gallignani P., Fresi E. & Cinelli F. (1982). Patterns of *Posidonia oceanica* (L.) Delile beds around the Island of Ischia (Gulf of Naples) and in adjacent waters. P.S.Z.N. Marine Ecology, 3 (1): 53- 74 + 2 maps.

Coleman, M. A., Kelaher, B. P., Steinberg, P. D. & Millar, A. J. K. (2008). Phyllospora lost: massive decline of an important habitatforming alga on urbanised rocky reefs around Sydney, Australia. Journal of Phycology, 44, 897-901.

Connell, S., Russell, B., Turner, D., Shepherd, A., Kildea, T., Miller, D., Airoldi, L. & Cheshire, A. (2008). Recovering a lost baseline: missing kelp forests from a metropolitan coast. Consorzio Unimar, Accordi di Programma Regione Campania - ottobre 2010.

Cormaci M., Furnari G., (1988). Sulla presenza nell'Italia meridionale di alcune alghe marine bentoniche rare per il Mediterraneo. Giorn. Bot. Ital., 122: 215-226.

Cormaci, M. & Furnari, G. (1999). Changes of the benthic algal flora of the Tremiti Islands (southern Adriatic) Italy. Hydrobiologia, 399, 75-79.

Cormaci, M., Furnari, G., Giaccone, G., Scammacca, B., & Serio, D. (1992). Observations taxonomiques et biogéographiques sur quelques espèces du genre *Cystoseira* C. Agardh. Bulletin de l'Institut océanographique, 21-35.

Cormaci, M., Furnari, G., Alongi, G., Catra, M., Pizzuto, F. & Serio, D. (2001). Spring marine vegetation on rocky substrata of the Tremiti Islands (Adriatic Sea, Italy). Nova Edwigia, 79, 447-478.

Cormaci M., Furnari, G., Catra M., Alongi G. & Giaccone G. (2012). Flora marina bentonica del Mediterraneo: Phaeophyceae. Bollettino dell'Accademia Gioenia di Scienze Naturali di Catania, 45, 1-508.

Costa, F., Krapp, T. & Ruffo S. (2009). Atlas of Mediterranean Amphipods, Mursia.

Costa A., (1870). La pesca nel Golfo di Napoli. Atti del R. Istituto d'Incoraggiamento alle Scienze Naturali Economiche e Tecnologiche di Napoli, seconda serie, 7: 33-128 + 8 tavv.

Costanza, R., d'Arge, R., de Groot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., Nsaeem, S., O'Neill, R.V., Paruelo, J., Raskìn, R.G., Sutton, P. & van den Belt, M. (1997). The value of the world's ecosystem service and natural capital. Nature, 387, 253-260

Council of Europe (1979). Convention on the Conservation of European Wildlife and Natural Habitats Convention relative à la conservation de la vie sauvage et du milieu naturel de l'Europe. Bern/Berne, 19.IX.1979. European Treaty Series 104. 23 pp., Appendices I & II. Cover, C. L. (2000). Corine Land Cover. European Environment Agency, Copenhagen.

Cronin, G. & Hay, M. E. (1996b). Susceptibility to herbivores depends on recent history of both the plant and animal. Ecology, 77 (5), 1531–1543.

Cronin, G., Hay, M.E., (1996a). Induction of seaweed chemical defenses by amphipod grazing. Ecology 77 (8), 2287–2301.

Çulha, M., Bat, L., Çulha, S. T. & Çelik, M. Y. (2010). Benthic mollusk composition of some facies in the upper-infralittoral zone of the southern Black Sea, Turkey. Turkish Journal of Zoology, 34(4), 523-532.

D'Archino, R., Lanera, P., Plastina, N., Valiante, L., Vinci, D., Dappiano, M. & Gambi, M. C. (2003). Check-list delle specie censite durante lo studio (A). In: Gambi, M. C., De Lauro, M., Jannuzzi, F., 2003. Ambiente marino costiero e territorio delle isole flegree (Ischia, Procida Vivara – Golfo di Napoli). Risultait di uno sutudio mutidisciplinare. Liguori Editore, pp 257-270.

Daniel, B., Piro, S., Charbonnel, E., Francour, P., & Letourneur, Y. (2009). Lessepsian rabbitfish *Siganus luridus* reached the French Mediterranean coasts. Cybium, 33(2), 163-164.

D'Argenio, B., Angelino, A., Aiello, G., de Alteriis, G., Milia, A., Sacchi, M., Tonielli, R., Budillon, F., Chiocci, F., Conforti, A., De Lauro, M., Di Martino, G., d'Isanto, C., Esposito, E., Ferraro, L., Innangi, S., Insinga, D., Iorio, M., Marsella, E., Molisso, F., Morra, V., Passaro, S., Pelosi, N., Porfido, S., Raspini, A., Ruggieri, S., Sarnacchiaro, G., Terranova, C., Vilardo, G. & Violante, C., (2004). Digital elevation model of the Naples bay and adjacent areas, eastern Tyrrhenian Sea. In: G. Pasquaré, C. Venturini and G. Groppelli, (eds.) Mapping geology in Italy, Rome APAT, Dipartimento Difesa del Suolo-Servizio Geologico d'Italia, pp. 21-28.

Dawson, E.Y. (1959). A primary report on the benthic marine flora of southern California in Oceanographic survey of the continental shelf area of southern California. Publs. Calif. St. Wat. Poll. Contr. Bd., 20:169-264

Dawson, E.Y. (1965). Chapter 8. Intertidal algae. In: An oceanographic and biological survey of the Southern California mainland shelf. Publs Calif. St. Wat. Qual. Control Bd 27, 220–231, 351–438.

Dayton, P. K. & Tegner, M. J. (1984). Catastrophic storms, El Niño, and patch stability in a southern California kelp community. Science, 224(4646), 283-285.

Dayton, P. K., Tegner, M. J., Parnell, P. E. & Edwards, P. B. (1992). Temporal and spatial patterns of disturbance and recovery in a kelp forest community. Ecological Monographs, 62(3), 421-445.

De Alteriis, G., Tonielli, R., Passaro, S., & De Lauro, M. (2006). Isole Flegree (Ischia e Procida). Liguori editore, Napoli, 73.

de los Reyes, C., Zbakh, H., Motilva, V. & Zubia, E. (2013). Antioxidant and Anti-inflammatory Meroterpenoids from the Brown Alga *Cystoseira usneoides*. Journal of Natural Products, 76,621-629.

De Maio, A., Moretti, M., Sansone, E., Spezie, G. & Vultaggio, M. (1979). Dinamica delle acque del Golfo di Napoli. Atti del Convegno Scientifico Nazionale PF Oceanografia e Fondi Marini II, 1033-1045.

De Masi F., Gargiulo G.M., (1982). *Rhodymenia deliculata* P.J.L. Dangeard (Rhodophyta Rhodymeniales) en Mediterranée. Giorn. Bot. Ital., 116: 117-121.

De Pippo, T., Donadio, C., Guida, M. & Petrosino, C. (2006). The Case of Sarno River (Southern Italy). Effects of geomorphology on the environmental impacts (8 pp). Environmental Science and Pollution Research, 13(3), 184-191.

Delle Chiaje, S. (1823). Hydrophytologia Regni Neapolitani.

Delizia, I. (2004). Ischia d'altri tempi. Electa Napoli.

Demirel, Z., Yildirim, Z. D., Tuney, I., Kesici, K. & Sukatar, A. (2012). Biochemical Analysis of Some Brown Seaweeds from the Aegean Sea. Botanica Serbica, 36, 91-95.

Desrosiers, G., Bellan-Santini, D. & Brêthes, J.C. (1982). Evolution spatio-temporelle des peuplements de substrats rocheux superficiels dans un golfe soumis à de multiples pollutions (Golfe de Fos, France). Téthys, 10 (3), 245–253.

Desrosiers, G., Bellan-Santini, D. & Brêthes, J.-C. (1986). Organisation trophique de quatre peuplements de substrats rocheux selon un gradient de pollution industrielle (Golfe de Fos, France). Marine Biology, 91, 107–120.

Desrosiers, G., Bellansantini, D., Brethes, J.C.F. & Willsie, A. (1990). Variability in trophic dominance of crustaceans along a gradient of urban and industrial contamination. Marine Biology, 105, 137-143.

Deudero, S., Frau, A., Cerda, M. & Hampel, H. (2005). Distribution and densities of the decapod crab *Percnon gibbesi*, an invasive Grapsidae, in western Mediterranean waters. Marine Ecology Progress Series, 285, 151-156.

Devescovi M. & Ivesa L. (2007). Short term impact of planktonic mucilage aggregates on macrobenthos along the Istrian rocky coast (Northern Adriatic, Croatia). Marine Policy Bullettin, 54, 887-893.

Diez, I., Secilla, A., Santolaria, A. & Gorostiaga, J. M. (1999). Phytobenthic intertidal community structure along an environmental pollution gradient. Marine Pollution Bulletin, 38, 463-472.

Diez, I., Santolaria, A., Secilla, A. & Gorostiaga J. M. (2009). Recovery stages over long-term monitoring of the intertidal vegetation in the 'Abra de Bilbao' area and on the adjacent coast (N. Spain). European Journal of Phycology, 44,1-14.

Díez, I., Muguerza, N., Santolaria, A., Ganzedo, U. & Gorostiaga J. M. (2012). Seaweed assemblage changes in the eastern Cantabrian Sea and their potential relationship to climate change. Estuarine Coastal and Shelf Science99:108–120

Dickinson, J.L., Shirk, J., Bonter, D., Bonney, R., Crain, R.L., Martin, J., Phillips, T. & Purcell, K. (2012). The current state of citizen science as a tool for ecological research and public engagement.Frontiers in Ecology and the Environment 10, 291–297.

Dixon, R. R., Mattio, L., Huisman, J. M., Payri, C. E., Bolton, J. J. & Gurgel, C. F. D. (2014). North meets south-Taxonomic and biogeographic implications of a phylogenetic assessment of *Sargassum* subgenera *Arthrophycus* and *Bactrophycus* (Fucales, Phaeophyceae). Phycologia, 53(1), 15-22.

Draisma, S. G. A., Ballesteros, E., Rousseau, F. & Thibaut, T. (2010). DNA sequence data demonstrate the polyphyly of the genus *Cystoseira* and other Sargassaceae genera (Phaeophyceae). Journal of Phycology, 46, 1329–1345.

Duarte, C. M. (1990). Seagrass nutrient content. Marine Ecology Progress Series. Oldendorf, 6(2), 201-207.

Ducklow, H. W., Doney, S. C. & Steinberg, D. K. (2009). Contributions of long-term research and time-series observations to marine ecology and biogeochemistry. Marine Science, 1.

EEA (2009)- "The Changing Faces of Europe's Coastal Areas", EEA Report 6/2009. Luxembourg: OPOCE.Online.Available //www.eea.europa.eu/publications/eea_report_2009_6/at_download/ file

Engkvist, R., Malm, T. & Tobiasson, S. (2000). Density dependent grazing effects of the isopod *Idotea baltica* Pallas on *Fucus vesiculosus* L in the Baltic Sea. Aquatic Ecology, 34(3), 253-260.

Ercegović, A., (1952). Fauna i Flora Jadrana. Jadranske cistozire. Njihova morfologija, ekologija i razvitak / Fauna et Flora Adriatica. Sur les Cystoseira adriatiques. Leur morphologie, écologie et évolution. Vol. 2 pp. 1-172 (Croatian), 173-210 (French), 211-212 (references), Map. Institut za Oceanografiju i Ribarstvo Split / Institut d'Océanograpie et de Peche, Split.

Eriksson, B. K., Johansson, G. & Snoeijs, P. (1998). Long-term changes in the sublittoral zonation of brown algae in the southern Bothnian Sea. European Journal of Phycology, 33(3), 241-249.

Ernst, J. (1959). Studien über die Seichtwasser-Vegetation der Sorrentiner Kuste. Pubblicazioni della Stazione Zoologica di Napoli, 30 suppl., 470-518.

Falace, A., Zanelli, E. & Bressan, G. (2005). Morphological and reproductive phenology of *Cystoseira compressa* (Esper) Gerloff & Nizamuddin (Fucales, Fucophyceae) in the Gulf of Trieste (North Adriatic Sea). In Annales. Series Historia Naturalis,Vol. 15, No. 1, pp. 71-78.

Falace, A., Zanelli, E., (2006). Studio morfo-funzionale, analisi della complessità e traspianto di habitat forming species (macrophytobenthos), in: Guido Bressan (a cura di), "Studio della produttività primaria e della produttività secondaria delle strutture artificiali sommerse poste in prossimità del Dosso di S. Croce Golfo di Trieste alto Adriatico", Trieste, EUT Edizioni Università di Trieste, 2006, pp. 59-72.

Falace, A., Zanelli, E. & Bressan, G. (2006). Algal transplantation as a potential tool for artificial reef management and environmental mitigation. Bulletin of Marine Science, 78 (1), 161-166.

Falace, A., Alongi, G., Cormaci, M., Furnari, G., Curiel, D., Cecere, E. & Petrocelli, A. (2010). Changes in the benthic algae along the Adriatic Sea in the last three decades. Chemistry and Ecology, 26(S1), 77-90.

Falkenberg, P. (1879). Die Meeres-Algen des Golfes von Neapel. (Nach Beobachtungen in der Zool. Station während der Jahre 1877-78 zusammengstellt). Mittheilungen Aus Der Zoologischen Station zu Neapel, 1 (3), 218-277.

Falkenberg, P. (1901). Die Rhodomelaceen des Golfes von Neapel und der angrenzenden Meeres-abschnitte. Fauna und Flora des Golfes von Neapel. Monographie 26. Berlin. Herausgegeben von der Zoologischen Station Zu Neapel. pp 754.

Faucci, A. & Boero, F. (2000). Structure of an epiphytic hydroid community on *Cystoseira* at two sites of different wave exposure. Scientia Marina, 64, 255-264.

Feldmann, J. (1937). Les algues marines de la Côte des Albéres. I-III. Cyanophycées, Chlorophycees et Pheophycees de la Côte des Albéres. Imprimerie Wolf. Rouen, 197 (pl I–X).

Feldmann, J. (1938). Recherches sur la vègétation marine de la Méditerranée. La Côte des Albéres. Revue Algologique, Fr., 10(1-4), 1-340.

Feldmann, G. (1941). Ecologie et repartition geographique des Ceramiacees mediterranéennes Bull. Soc.. Hist. Nat. Af. Nord ,32 : 62-78.

Feoli, E. & Bressan, G. (1972). Affinità floristica dei tipi di vegetazione bentonica della Cala di Mitigliano (Massa Lubrense, Napoli). Giornale Botanico Italiano, 106, 245-256.

Fernández, C. & Niell, F.X. (1982). Zonación de fitobentos intermareal de la región de Cabo Peñas (Asturias). Investigacion Pesquera (Spain), 46, 121–141

Fernández, C. (2011). The retreat of large brown seaweeds on the north coast of Spain: the case of *Saccorhiza polyschides*. European Journal of Phycology, 46(4), 352-360.

Ferrario, F., Iveša, L., Jaklin, A., Perkol-Finkel, S. & Airoldi, L. (2016). The overlooked role of biotic factors in controlling the ecological performance of artificial marine habitats. Journal of Applied Ecology, 53(1), 16-24.

Ferretti M., (2011). Capture fisheries. In: Cataudella S. & Spagnolo M. (eds), 2011 - The state of Italian marine fisheries and aquaculture. Ministero delle Politiche Agricole, Alimentari e Forestali (MiPAAF), Rome (Italy), 620 p.

Ferretti, F., Osio, G. C., Jenkins, C. J., Rosenberg, A. A., & Lotze, H. K. (2013). Long-term change in a meso-predator community in response to prolonged and heterogeneous human impact. Scientific reports, 3, 1057.

Ferrigno, F., Boi, S., Cinti, M. F., Paliaga, B. & Guala, I. (2014). Spatial and temporal distribution of shallow assemblages in the Marine Protected Area of Capo Carbonara (Sardinia). Biologia Marina Mediterranea, 21(1), 257-258.

Ferrigno, F., Sandulli, R. & Russo, G. F. (2016). Fishing impacts on coralligenous assemblages of “Secchitiello” shoal (Gulf of Naples, Italy) 47° Congresso della Società Italiana di Biologia Marina Torino, 13-17 giugno 2016.

Firth, L. B., Thompson, R. C., White, F. J., Schofield, M., Skov, M. W., Hoggart, S. P. G, Jackson, J., Knights A. M. & Hawkins, S. J. (2013). The importance of water-retaining features for biodiversity on artificial intertidal coastal defence structures. Diversity and Distributions, 19(10), 1275-1283.

Flagella, M. M., Soria, A. & Buia, M. C. (2006). Shipping traffic and introduction of non-indigenous organisms: study case in two Italian harbours. Ocean and Coastal Management, 49 (12), 947-960.

Flagella, M. M., Verlaque, M., Soria, A., & Buia, M. C. (2007). Macroalgal survival in ballast water tanks. Marine pollution bulletin, 54(9), 1395-1401.

Fleet register (2012), Available at : http://ec.europa.eu/fisheries/fleet/index.cfm

Frantzis, A. & Gremare, A. (1992). Ingestion, absorption and growth rates of *Paracentrotus lividus* (Echinodermata: Echinoidea) fed different macrophytes. Marine Ecology Progress Series, 95, 169–183.

Fraschetti, S., Gambi, M.C., Giangrande, A., Musco, L., Terlizzi, A. & Danovaro, R. (2006). Structural and functional response of meiofauna rocky assemblages to sewage pollution. Marine Pollution Bulletin, 52, 540-548.

Fraschetti, S., Guarnieri, G., Bevilacqua, S., Terlizzi, A., Claudet, J., Russo, G. F. & Boero, F. (2011). Conservation of Mediterranean habitats and biodiversity countdowns: what information do we really need?. Aquatic Conservation: Marine and Freshwater Ecosystems, 21(3), 299-306.

Fraschetti, S., Bevilacqua, S., Guarnieri, G. & Terlizzi, A. (2012). Idiosyncratic effects of protection in a remote marine reserve. Marine Ecology Progress Series, 466, 21-34.

Franzese PP, Buonocore E, Paoli C, Massa F, Stefano D, Fanciulli G, Miccio A, Mollica E, Navone A, Russo GF, Povero P, Vassallo P. Environmental accounting in marine protected areas: the EAMPA Project. J Environ Account Manag. 2015;3:324–32.

Funk, G. (1927). Die Algenvegetation des Golfs von Neapel. Pubblicazioni della Stazione Zoologica di Napoli, 7, 1-507 + 20 Tavv.

Funk, G. (1955). Meeresalgen von Neapel. Pubblicazioni della Stazione Zoologica di Napoli, 25, 1-178 + 30 Tavv.

Furnari, G., Cormaci, M. & Serio, D. (1999). Catalogue of the benthic marine macroalgae of the Italian coast of the Adriatic Sea (Vol. 12). Herbarium Mediterraneum.

Furnari, G., Giaccone, G. & Cormaci, M. (2003). Biodiversità marina delle coste italiane: catalogo del macrofitobenthos. Societa italiana di biologia marina.

Furnari, G. (2010). Le macroalghe delle coste italiane: aspetti floristici e vegetazionali. Bollettino Accademia Gioenia di Scienze Naturali in Catania, 43(371), 1-17.

Fusi, N., Mirabile, L. & Camerlenghi, A. (1991). Marine geophysical survey of the Gulf of Naples (Italy): Relationship between submarine volcanic activity and sedimentation. Memorie della Società Italiana di Geologia, 47, 95-114, 13 ff.

Gambi, M.C., Zupo, V. & Lorenti, M. (2000). Borer organisms of the *Posidonia oceanica* scales: trophic role and ecological implications for the ecosystem. Biologia Marina Mediterranea, 7(1), 253-261.

Gambi, M. C., Dappiano M., Lanere P. & Iacono F. (2003a). Biodiversita' e bionomia dei popolamenti bentonici dei fondali duri delle isole flegree: analisi di diverse metodologie di studio. In: Gambi M.C., De Lauro M., Jannuzzi F. 2003. Ambiente marino costiero e territorio delle isole flegree (Ischia, Procida Vivara – Golfo di Napoli). Risultait di uno sutudio mutidisciplinare. Liguori Editore, pp 133-161.

Gambi, M. C., De Lauro, M. & Jannuzzi, F. (2003b). Ambiente marino costiero e territorio delle isole Flegree (Ischia Procida Vivara - Golfo di Napoli). Risultati di uno studio multidisciplinare. Società Nazionale delle Scienze, Lettere ed Arti in Napoli, Memorie dell'Accademia di Scienze Fisiche e Matematiche, 5, 425 pp.

Gambi, M. C., Dappiano, M., Lorenti, M., Iacono, B., Flagella, S. & Buia, M. C. (2005), ''Chronicle of a death foretold'' – features of a *Posidonia oceanica* bed impacted by sand extraction. In: Özhan E. (Ed), Proceedings of the Seventh International Conference on the Mediterranean Coastal Environment, MEDCOAST 05, 25–29 October 2005. Kusadasi, Turkey, 441–450.

Gambi, M. C., Russo, G. F., Cigliano, M. & Di Stefano, F. (2009). Implementazione dei SIC Marini Italiani: Campania, Basilicata, Calabria. Italian Report Program of Ministero dell'Ambiente e della Tutela del Territorio e del Mare, 47 pp.

Gamulin-Brida, E. (1965). Contribution aux recherches sur la bionomie bentique de la baie de Porto Paone (Naples, Italie). Repartition des biocenoses bentiques. Pubblicazioni della Stazione Zoologica di Napoli, 34, 476-500.

Gamulin-Brida, H., Giaccone, G. & Golubić, S. (1967). Contribution aux études des biocoenoses subtidales. Helgoländer wissenschaftliche Meeresuntersuchungen, 15(1), 429.

García-Sánchez, M., Korbee, N., Pérez-Ruzafa, I. M., Marcos, C., Figueroa, F. L. & Pérez-Ruzafa, Á. (2014). Living in a coastal lagoon environment: photosynthetic and biochemical mechanisms of key marine macroalgae. Marine Environmental Research, 101, 8–21.

Garrard, S.L. (2013). The effect of ocean acidification on plant-animal interactions in a Posidonia oceanica meadow - PhD Thesis Open University, Milton Keynes, London – Stazione Zoologica Anton Dohrn Napoli.

Garreta, A. G., Gallardo, T., Ribera, M. A., Cormaci, M., Furnari, G., Giaccone, G. & Boudouresque, C.F. (2001). Checklist of Mediterranean seaweeds. III. Rhodophyceae Rabenh. 1. Ceramiales Oltm. Botanica Marina, 44 (5), 425-460.

Geoportale Nazionale, "Ministero dell'Ambiente." from: http://wms. pcn. minambiente. it

Gerloff, J. & Nizamuddin, M. (1976). New species of the genus *Cystoseira* C. Ag. Nova Hedwigia, 27, 167-182.

Giaccone, G. (1969). Raccolte di fitobenthos sulla banchina continentale italiana. Giornale Botanico Italiano, 103, 485-514.

Giaccone G., Bruni A. (1973). Le Cistoseire e la vegetazione sommersa del Mediterraneo. Estratto dagli Atti dell' Istitutuo Veneto di Scienze, Lettere ed Arti, 131 : 59-103.

Giaccone, G., & Geraci, R. M. (1989). Biogeografia delle alghe del Mediterraneo. In: Anales del Jardín Botánico de Madrid (Vol. 46, No. 1, pp. 27-34). Real Jardín Botánico.

Giaccone, G. (1999). L'origine della biodiversità vegetale del Mediterraneo. Notiziario S.I.B.M., 35, 35-51.Giakoumi, S., Cebrian, E., Kokkoris, G. D., Ballesteros, E. & Sala, E. (2012). Relationships between fish, sea urchins and macroalgae: The structure of shallow rocky sublittoral communities in the Cyclades, Eastern Mediterranean. Estuarine, Coastal and Shelf Science, 109, 1-10.

Gianni, F., Bartolini, F., Airoldi, L., Ballesteros, E., Francour, P., Guidetti, P., Meinesz, A., Thibaut, T. & Mangialajo, L. (2013). Conservation and restoration of marine forests in the Mediterranean Sea and the potential role of Marine Protected Areas. Advances in Oceanography and Limnology, 4, 83-101.

Gianni, F. & Mangialajo, L. (2014). Are Mediterranean MPAs protecting marine forests?. Proceeding of the 5th Mediterranean Symposium on Marine Vegetation, RAC-SPA, Portorož, Slovenia, 27-28 October 2014, 28-33.

Gianni, F. & Mangialajo, L. (2016). Guidelines for the conservation, monitoring and restoration of *Cystoseira* forests in the Mediterranean Sea. In: MMMPA Supervisory Board (ed) Monitoring Mediterranean Marine Protected Areas: A set of guidelines to support the development of management plans Deliverable of the MMMPA European project (FP7-PEOPLE-2011-ITN ga no: 290056), Reef Check Italia onlus, Ancona, p 9-17 ISBN 978-88-906783-4-9

Gill, D. A., Mascia, M. B., Ahmadia, G. N., Glew, L., Lester, S. E., Barnes, M. Ian Craigie, Emily S. Darling, Christopher M. Free, Jonas Geldmann, Susie Holst, Olaf P. Jensen, Alan T. White, Xavier Basurto, Lauren Coad, Ruth D. Gates, Greg Guannel, Peter J. Mumby, Hannah Thomas, Sarah Whitmee Holst, S. (2017). Capacity shortfalls hinder the performance of marine protected areas globally. Nature.

Gomez-Garreta, A., Barceló, M., Gallardo, T., Pérez-Ruzafa, I., Ribera, M.A. Rull, L. (2001). Flora Phycologica Iberica. Vol. 1 Fucales. Servicio de Publicaciones, Universidad de Murcia, Spain. 192 pp.

Gozler, A. M., Kopuz, U. & Agirbas, E. (2010). Seasonal changes of invertebrate fauna associated with *Cystoseira barbata* facies of Southeastern Black Sea coast. African Journal of Biotechnology, 9(51), 8852.

Grech, D., Chiarore, A., Fioretti, S., Kumar, A., Mulas, M., Buia, M. C. & Patti, F. P. (2015a). The importance of an integrated approach in the study, conservation and restoration of Fucales. Biologia Marina Mediterranea, 22, 32-33.

Grech, D., Patti, F. P., Chiarore, A., Mulas, M. & Buia, M. C. (2015b). Coastal Transformation and Marine Habitat Loss. In: Ozhan E. (ed.), Proceedings of the Twelfth International Conference on the Mediteranean Coastal Environment, MEDCOAST 2015. Varna (Bulgaria), 6–10 Oct 2015, 1, 271-281.

Grieco, L., Tremblay, L. B. & Zambianchi, E. (2005). A hybrid approach to transport processes in the Gulf of Naples: an application to phytoplankton and zooplankton population dynamics. Continental Shelf Research, 25, 711-728.

Group, The MerMex, et al. (2011). Marine ecosystems responses to climatic and anthropogenic forcings in the Mediterranean." Progress in Oceanography, 91.2: 97-166.

Guala, I., Esposito, A. & Buia, M. C. (2006). Macroalgal assemblages in the Gulf of Naples: spatial variability in relation to anthropogenic disturbance. In: United Nations Environment Programme (Ed.), Proceedings of the Second Mediterranean Symposium on Marine Vegetation. Regional Activity Centre for Specially Protected Areas, Tunis, Tunisia, pp. 168–174.

Guern, M. (1962). Embryologie de quelques espèces du genre *Cystoseira* Agardh 1821 (Fucales). Vie Milieu, 13, 649-679.

Guidetti, P., Fraschetti, S., Terlizzi, A. & Boero, F. (2003). Distribution patterns of sea urchins and barrens in shallow Mediterranean rocky reefs impacted by the illegal fishery of the rock-boring mollusc *Lithophaga lithophaga*. Marine Biology, 143(6), 1135-1142.

Guidetti, P. (2006). Marine reserves reestablish lost predatory interactions and cause community changes in rocky reefs. Ecological Applications, 16(3), 963-976.

Guidetti, P., Milazzo, M., Bussotti, S., Molinari, A., Murenu, M., Pais, A., Carrada, G. (2008). Italian marine reserve effectiveness: Does enforcement matter?. Biological Conservation, 141(3), 699-709.

Guiry M.D. in Guiry, M.D. & Guiry, G.M. 2016. AlgaeBase. World-wide electronic publication, National University of Ireland, Galway. http://www.algaebase.org

Gunnill, F. C. (1980). Demography of the intertidal brown alga *Pelvetia fastigiata* in southern California, USA. Marine Biology, 59(3), 169-179.

Haahtela, I. (1984). A hypothesis of the decline of the bladder wrack (*Fucus vesiculosus* L.) in SW Finland in 1975–1981. Limnologica, 15(2), 345-350.

Hagen, N. T. (1995). Recurrent destructive grazing of successionally immature kelp forests by green sea urchins in Vestfjorden, Northern Norway. Marine Ecology Progress Series, 123, 95-106.

Hall-Spencer, J. M., Rodolfo-Metalpa, R., Martin, S., Ransome, E., Fine, M., Turner, S. M., Rowley, S. J., Tedesco, D. & Buia, M.-C. (2008). Volcanic carbon dioxide vents show ecosystem effects of ocean acidification. Nature, 454, 96-99.

Halpern, B. J., Walbridge, S., Selkoe, K. A, Kappel, C. V., Micheli, F., D'Agrosa, C., Casey, K. S., Ebert, C., Fox, H., Fujita, R., Heinemann, D., Lenihan, H. S., Madin, E. M. P., Perry, T. M., Selig, E. R., Spalding, M., Steneck, R. & Watson, R. (2008). A Global Map of Human Impact on Marine Ecosystems. Science, 139, 948-952.

Hanel, R. (2002). Recovery of Fucacean associations and associated fish assemblages in the vicinity of Rovinj, Istrian coast, northern Adriatic Sea. Periodicum Biologorum, 104(2), 159-163.

Harmelin-Viven, M. L. & Francour, P. (1992). Trawling or visual censuses? Methodological bias in the assessment of fish populations in seagrass beds. Marine Ecology, 13(1), 41-51.

Harnik, P. G., Lotze, H. K., Anderson, S. C., Finkel, Z. V., Finnegan, S., Lindberg, D. R., Liow, L. H., Lockwood, R., McClain, J. L., McGuire, A. O'Dea, Pandolfi, J. M., Simpson, C., Tittensor, D. P. (2012). Extinctions in ancient and modern seas. Trends Ecol. Evol. 27: 608–617.

Harrison, P. & Pearce F. (2001). Atlas of Population and Environment. University of California Press, Berkeley.

Harrold, C. & Reed, D. C. (1985). Food availability, sea urchin grazing, and kelp forest community structure. Ecology, 66(4), 1160-1169.

Havelange, S., Lepoint, G., Dauby, P. & Bouquegneau, J. M. (1997). Feeding of the sparid fish *Sarpa salpa* in a seagrass ecosystem: diet and carbon flux.Marine Ecology, 18(4), 289-297.

He, Q. & Silliman, B. R. (2016). Consumer control as a common driver of coastal vegetation worldwide. Ecological Monographs, 86, 278-294.

Hedges, J. I. & Stern, J. H. (1984). Carbon and nitrogen determinations of carbonate containing solids. Limnology and Oceanography, 29(3), 657-663.

Hereu, B., Mangialajo, L., Ballesteros, E. & Thibaut, T. (2008). On the occurrence, structure and distribution of deep-water *Cystoseira* (Phaeophyceae) populations in the Port-Cros National Park (north-western Mediterranean). European Journal of Phycology, 43(3), 263-273.

Hereu, B., Rodríguez, A., Linares, C., Díaz, D., Riera, J. L., & Zabala, M. (2010). Cartografia bionòmica del litoral submergit de la costa del Montgrí. Diputació de Girona, Girona.

Hereu, B., Zabala, M., Linares, C. & Sala, E. (2004). Temporal and spatial variability in settlement of the sea urchin *Paracentrotus lividus* in the NW Mediterranean. Marine Biology, 144(5), 1011-1018.

Hsu, K. J. (1982). The Mediterranean Was a Desert: A Voyage of the Glomar Challenger. Princeton University Press, Princeton, New Jersey, 197 pp.

Huvé, P. (1970). Recherche sur la genèse de quelques peuplements algaux marins de la roche littorale de la région de Marseille. Thèse Doctorat d'Etat. Faculté des Sciences de Paris, 479 p.

Iermano, I., Liguori, G., Iudicone, D., Nardelli, B. B., Colella, S., Zingone, A. & d'Alcalà, M. R. (2012). Filament formation and evolution in buoyant coastal waters: Observation and modelling. Progress in Oceanography, 106, 118-137.

Imperato, F. (1589). Dell'Historia Naturale libri XXXVIII. Napoli fol. con fig.

Irving, A. D., Balata, D., Colosio, F., Ferrando, G. A. & Airoldi, L. (2009). Light, sediment, temperature, and the early life-history of the habitat-forming alga *Cystoseira barbata*. Marine Biology, 156(6), 1223-1231.

Istat, (2013) ISTAT, Bilancio demografico e popolazione residente al 31 Dicembre, Roma

IUCN (2012) IUCN Red list categories and criteria: version 3.1. Second edition. IUCN, Gland, Switzerland and Cambridge, UK, pp 32.

IUCN (2016) The IUCN Red List of Threatened Species.www.iucnredlist.org.

Iveša, L. & Devescovi, M. (2014). Distribution and composition of *Cystoseira* stands along the west Istrian coast (northern Adriatic, Croatia) and comparison with historical data. In 5th Mediterranean Symposium on Marine Vegetation.

Iveša, L., Djakovac, T. & Devescovi, M. (2016). Long-term fluctuations in *Cystoseira* populations along the west Istrian Coast (Croatia) related to eutrophication patterns in the northern Adriatic Sea. Marine Pollution Bulletin, 106(1), 162-173.

Jackson, J. B. C. 1997. Reefs since Columbus. Coral Reefs 16: S23–S32.

Jackson, J. B., Kirby, M. X., Berger, W. H., Bjorndal, K. A., Botsford, L. W., Bourque, B. J., & Hughes, T. P. (2001). Historical overfishing and the recent collapse of coastal ecosystems. Science, 293(5530), 629-637.

Jadot, C., Graux, D., Michel, C., & Voss, J. (2000). Contribution à la caractérisation du comportement reproducteur et alimentaire de la Saupe (*Sarpa salpa* (Linné, 1758)). Cah. Ethol. Appl, 20, 33-44.

Jadot, C., Ovidio, M. & Voss, J. (2002). Diel activity of *Sarpa salpa* (Sparidae) by ultrasonic telemetry in a *Posidonia oceanica* meadow of Corsica (Mediterranean Sea). Aquatic Living Resources, 15(6), 343-350.

Jadot, C., Donnay, A., Acolas, M. L., Cornet, Y. & Anras, M. B. (2006). Activity patterns, home-range size, and habitat utilization of *Sarpa salpa* (Teleostei: Sparidae) in the Mediterranean Sea. ICES Journal of Marine Science: Journal du Conseil, 63(1), 128-139.

Jones, C. G., Lawton, J. H. & Shachak, M. (1994). Organisms as ecosystem engineers. In Ecosystem management (pp. 130-147). Springer New York.

Jones, C. G., Lawton, J. H., & Shachak, M. (1997). Positive and negative effects of organisms as physical ecosystem engineers. Ecology, 78(7), 1946-1957.

Kangas, P., Autio, H., Hallfors, G., Luther, H., Niemi, A. & Salemaa, H. (1982). General model of the decline of *Fucus vesiculosus* at Tvarminne, south coast of Finland in 1977-81. Acta Botanica Fennica 118:1-27.

Kangas, P. & Hällfors, G. (1985). On the decline of *Fucus vesiculosus* at the south coast of Finland. Academy of Sciences of the Estonian SSR Institute of Zoology and Botany, Hydrobiological Researches XV.

Kautsky, N., Kautsky, H., Kautsky, U. & Waern, M. (1986). Decreased depth penetration of *Fucus vesiculosus* (L.) since the 1940's indicates eutrophication of the Baltic Sea. Marine Ecology Progress Series, 28, 1–8.

Kautsky, H. (1992). The impact of pulp-mill effluents on the phytobenthic communities in the Baltic Sea. Acta Phytogeogr. Suec. 78, 33–48.

Kennelly, S. J. (1987). Inhibition of kelp recruitment by turfing algae and consequences for an Australian kelp community. Journal of Experimental Marine Biology and Ecology, 112(1), 49-60.

Keser, M., Swenarton, J. T. & Foertch, J. F. (2005). Effects of thermal input and climate change on growth of *Ascophyllum nodosum* (Fucales, Phaeophyceae) in eastern Long Island Sound (USA). Journal of Sea Research, 54, 211-220.

Kiirikki, M. (1996). Mechanisms affecting macroalgal zonation in the northern Baltic Sea. European Journal of Phycology, 31, 225–232.

Kiirikki, M., Ruuskanen A., (1996). How does Fucus vesiculosus survive ice scraping? Botanica marina, 39: 133-139.

Kocataş, A., Katağan, T., Sezgin, M., Kirkim, F. & Koçak, C. (2004). Crustacean diversity among the *Cystoseira* facies of the Aegean Coast of Turkey. Turkish Journal of Zoology, 28(4), 309-316.

Kostenko, N. S., Dikiy, Y. A. & Zakletskiy, A. A. (2006). Present-Day State of Macrophytobenthos of Shelf Zones of the Black Sea (Southeastern Crimea). Hydrobiological Journal, 42(4).

Kumar, A. (2015) *Sargassum vulgare* adaptation under natural acidified conditions. PhD Thesis Open University, Milton Keynes, London – Stazione Zoologica Anton Dohrn Napoli.

Kumar A., Castellano I., Patti F. P., Delledonne M., Abdelgawad H., Beemster G. T. S., Asard H., Palumbo A. & Buia M. C (2017). Molecular response of *Sargassum vulgare* to acidification at volcanic CO2 vents: insights from de novo transcriptomic analysis. Molecular Ecology.

Kumar, A., Abdelgawad, H., Castellano, I., Lorenti, M., Delledonne, M., Beemster, T.S.G., Asard, H., Buia, M.C., Palumbo, A. (2017). Physiological and biochemical analysis shed light on the response of Sargassum vulgare to ocean acidification at different time scales. Frontiers in Plant Sciences (in press) DOI: 10.3389/fpls.2017.00570

Kützing, F.T. (1860). Tabulae phycologicae; oder, Abbildungen der Tange. Vol. X pp. i-iv, 1-39, 100 pls. Nordhausen: Gedruckt auf kosten des Verfassers.

Langella A. (2011). La pesca delle spugne. www.vesuvioweb.com.

Langmead, O., McQuatters-Gollop, A., Mee, L. D., Friedrich, J., Gilbert, A. J., Gomoiu, M. T., & Todorova, V. (2009). Recovery or decline of the northwestern Black Sea: A societal choice revealed by socio-ecological modelling. Ecological Modelling, 220(21), 2927-2939.

Lejeusne, C., Chevaldonne, P., Pergent-Martini, C., Boudouresque, C. F. & Perez, T. (2010). Climate change effects on a miniature ocean: the highly diverse, highly impacted Mediterranean Sea. Trends in Ecology & Evolution, 25(4), 250-260.

Leonetti, E. (2004). Napoli e Salerno: due porti a confronto. http://www.porto.napoli.it/it/news/PDF/newsletter/it6.pdf

Llimona, X., Ballesteros, E., Brugués, M., Comín, F., Cros, R., Molero, J. & Torrella, F. (1985). Plantes inferiors. Història Natural dels Països Catalans, 4.

Lo Bianco, S. (1909). Notizie biologiche riguardanti specialmente il periodo di maturita sessuale degli animali del Golfo di Napoli. Mittheilungen aus der Zoologischen Station zu Neapel, 19 (4): 513-761.

Lorenti, M., Buia, M. C., Di Martino, V., & Modigh, M. (2005). Occurrence of mucous aggregates and their impact on *Posidonia oceanica* beds. Science of the total environment, 353(1), 369-379.

Lotze, H. K., Lenihan, H. S., Bourque, B. J., Bradbury, R. H., Cooke, R. G., Kay, M. C. & Jackson, J. B. (2006). Depletion, degradation, and recovery potential of estuaries and coastal seas. Science, 312(5781), 1806-1809.

Lotze, H. K. & Worm, B. (2009). Historical baselines for large marine animals. Trends in Ecology & Evolution, 24(5), 254-262.

Lotze, H. K., Coll, M., & Dunne, J. A. (2011). Historical changes in marine resources, food-web structure and ecosystem functioning in the Adriatic Sea, Mediterranean. Ecosystems, 14(2), 198-222.

Lotze, H. K., & McClenachan, L. (2014). Marine historical ecology: informing the future by learning from the past. Marine community ecology and conservation, 165-200

Lundälv, T., Larsson, C. S. & Axelsson, L. (1986). Long-term trends in algal-dominated rocky subtidal communities on the Swedish west coast—a transitional system?. Hydrobiologia, 142(1), 81-95.

Lüning, K. (1990). Seaweeds. Their environment, biogeography, and ecophysiology. Wiley and Sons ed., New York, pp 1-527.

Macic, V., Antolic, B., Thibaut, T. & Svircev, Z. (2010). Distribution of the most common *Cystoseira* C. agardh species (Heterokontophyta, Fucales) on the coast of Montenegro (South-East Adriatic Sea). Fresenius Environmental Bulletin, 19(6), 1191-1198.

Maibam, C., Fink, P., Romano, G., Buia, M. C., Gambi, M. C., Scipione, M. B. & Zupo, V. (2014). Relevance of wound-activated compounds produced by diatoms as toxins and infochemicals for benthic invertebrates. Marine biology, 161(7), 1639-1652.

Malm, T., Engkvist, R. & Kautsky, L. (1999). Grazing effects of two freshwater snails on juvenile *Fucus vesiculosus* in the Baltic Sea. Marine Ecology Progress Series, 188: 63–71.

Mancuso, F. P., D'hondt, S., Willems, A., Airoldi, L. & De Clerck, O. (2016). Diversity and Temporal Dynamics of the Epiphytic Bacterial Communities Associated with the Canopy-

Forming Seaweed *Cystoseira compressa* (Esper) Gerloff and Nizamuddin. Frontiers in microbiology, 7.

Mangialajo, L., Ruggieri, N., Asnaghi, V., Chiantore, M., Povero, P., & Cattaneo-Vietti, R. (2007). Ecological status in the Ligurian Sea: the effect of coastline urbanisation and the importance of proper reference sites. Marine Pollution Bulletin, 55(1), 30-41.

Mangialajo, L., Chiantore, M. & Cattaneo-Vietti, R. (2008). Loss of fucoid algae along a gradient of urbanisation, and structure of benthic assemblages. Marine Ecology Progress Series, 358, 63-74.

Mangialajo, L., Chiantore, M., Susini, M. L., Meinesz, A., Cattaneo-Vietti, R. & Thibaut, T. (2012). Zonation patterns and interspecific relationships of fucoids in microtidal environments. Journal of Experimental Marine Biology and Ecology, 412, 72-80.

Mannino, A. M. & Mancuso F. P. (2009). Guida all'identificazione delle Cistoseire (Area Marina Protetta" Capo Gallo-Isola delle Femmine"). Palermo, Tipografia Alba, 79 p.

Mannino, A. M., Vaglica, V. & Oddo, E. (2014). Seasonal variation in total phenolic content of *Dictyopteris polypodioides* (Dictyotaceae) and *Cystoseira amentacea* (Sargassaceae) from the Sicilian coast. Fl Med, 24, 39-50.

Mariani, S., Cefalì, M. E., Terradas, M., Chappuis, E. & Ballesteros, E. (2014). Using catenas for GIS-based mapping of NW Mediterranean littoral habitats. Estuarine, Coastal and Shelf Science, 147, 56-67.

Mazza, A. (1902). Flora marina del Golfo di Napoli. Contribuzione I. Nuova Notarisia, 13, 125-152.

Mazza, A. (1903). Flora marina del Golfo di Napoli. Contribuzione I. Aggiunta alle Floridee. Nuova Notarisia, 14, 1-17.

Mazzarelli, G. & Mazzarelli, G. (1918). Prime indagini sui banchi di corallo del Golfo di Napoli. Annali di Idrobiologia e Pesca, Pavia, 1, 1–42.

Mazzella, L. & Russo, G. F. (1989). Grazing effect of two *Gibbula* species (Mollusca, Archeogasteropoda) on the epiphytic community of *Posidonia oceanica* leaves. Aquatic Botany, 35, 357–373.

Mazzella, L., Buia, M. C., Gambi M. C., Lorenti, M. Russo G. F., Scipione M. B. & Zupo, V. (1992). Plant-animal trophic relationships in the *Posidonia oceanica* ecosystem of the Mediterranean Sea: a review. In: D. John, S. 1. Hawkins & J. H. Price (Eds.), Plant-Animal Interactions in the Marine Benthos, Systematics Association Special Volume No. 46, Clarendon Press, Oxford, pp. 165-187.

McClanahan, T. R. & Sala, E. (1997). A Mediterranean rocky-bottom ecosystem fisheries model. Ecological Modelling, 104(2), 145-164.

Menge, B. A., Berlow, E. L., Blanchette, C. A., Navarrete, S. A. & Yamada, S. B. (1994). The keystone species concept: variation in interaction strength in a rocky intertidal habitat. Ecological Monographs, 64 (3), 249-286.

Menna, M. (2007) Misure di correnti superficiali nel Golfo di Napoli eseguite con radar costiero PhD thesis Università Degli Studi Di Napoli “Federico II”.

Messner, U. & von Oertzen, J. A. (1991). Long-term changes in the vertical distribution of macrophytobenthic communities in the Greifswalder Bodden. Acta Ichthyologica et Piscatoria. Supplementum, 21.

Micheli, F., Halpern, B. S., Walbridge, S., Ciriaco, S., Ferretti, F., Fraschetti, S. & Rosenberg, A. A. (2013). Cumulative human impacts on Mediterranean and Black Sea marine ecosystems: assessing current pressures and opportunities. PLoS One, 8(12), e79889.

Middelboe, A. L. & Sand-Jensen, K. (2000). Long-term changes in macroalgal communities in a Danish estuary. Phycologia, 39(3), 245-257.

Milazzo, M., Chemello, R., Badalamenti, F. & Riggio, S. (2002). Short-term effect of human trampling on the upper infralittoral macroalgae of Ustica Island MPA (western Mediterranean, Italy). Journal of the Marine Biological Association of the United Kingdom 82, 745-748.

Milchakova, N. A. & Phillips, R. C. (2003). Black sea seagrasses. Marine pollution bulletin, 46(6), 695-699.

Millenium Ecosystem Assessment (2005). Ecosystems and human well-being: Synthesis Report. World Resources Institute. Washington, DC.

Mineur, F., Arenas, F., Assis, J., Davies, A. J., Engelen, A. H., Fernandes, F. & Vranken, S. (2015). European seaweeds under pressure: consequences for communities and ecosystem functioning. Journal of Sea Research, 98, 91-108.

Minicheva, G. G. (2007). Contemporary morpho-functional transformation of seaweed communities of the Zernov phyllophora field (Black Sea). International Journal on Algae, 9(1).

Miraglia F. (1941). Rivista fisica di matematica e scienze naturali. 16(1941) Secca del Frontone pag.62-70.

Molinier, R., 1960. Etude des biocénoses marines du Cap Corse. Vegetatio, 9 (4-5), 217-312.

Monteiro, C. A., Engelen, A. H. & Santos, R. O. P. (2009). Macro- and mesoherbivores prefernative seaweeds over the invasive brown seaweed *Sargassum muticum*: a potential regulating role on invasions. Marine Biology, 156, 2505–2515.

Moreno, D., de la Linde, A., Arroyo, M.C., López-González, P.J., (2008). *Astroides calycularis* (Pallas, 1766). In: Barea-Azcón, J.M., Ballesteros-Duperón, E., Moreno, D. (Coords.), Libro Rojo de los Invertebrados de Andalucía. Tomo 1. Consejería de Medio Ambiente, Junta de Andalucía, Sevilla, pp. 281–287.

Moschella, P. S., Abbiati, M., Åberg, P., Airoldi, L., Anderson, J. M., Bacchiocchi, F., & Granhag, L. (2005). Low-crested coastal defence structures as artificial habitats for marine life: using ecological criteria in design. Coastal Engineering, 52(10), 1053-1071.

Mulas, M. (2013) Popolamenti a *Cystoseira* nel Golfo di Napoli: effetti antropici e interazioni biotiche, Master Thesis, Università Politecnica delle Marche, Italy.

Munda, I. M., (1974). Changes and succession in the benthic algal associations of slightly polluted habitats. Oceanographic Literature Review. Med. 34, 37–52.

Munda, I. M. (1982) The effects of organic pollution on the distribution of fucoid algae from the Istrian coast (vicinity of Rovinj). Acta Adriatica 23, 329–337.

Munda, I. M. (1993). Changes and degradation of seaweed stands in the Northern Adriatic. In Fourteenth International Seaweed Symposium (pp. 239-253). Springer Netherlands.

Munda, I. (2000). Long-term marine floristic changes around Rovinj (Istrian coast, North Adriatic) estimated on the basis of hystorical data from Paul Kuckuck's field diaries from the end of the 19th century. Nova Hedwigia, 71 (1-2): 1.36.

Murray, S. N. & Littler, M. M. (1984). Analysis of seaweed communities in a disturbed rocky intertidal environment near Whites Point, Los Angeles, Calif., USA. In Eleventh International Seaweed Symposium, pp. 374-382. Springer Netherlands.

Mussi, B. & Miragliuolo, A. 2003. I cetacei della costa nord-occidentale dell'isola di Ischia (Canyon di Cuma). In: Gambi, M.C., De Lauro, M., Jannuzzi, F. (Eds.), Ambiente marino costiero e territorio delle isole Flegree (Ischia Procida Vivara – Golfo di Napoli). Risultati di uno studio multidisciplinare. Società Nazionale di Scienze, Lettere e Arti in Napoli, Napoli, pp. 212-232.

Navarro, L., Ballesteros, E., Linares, C. & Hereu, B. (2011). Spatial and temporal variability of deep-water algal assemblages in the Northwestern Mediterranean: The effects of an exceptional storm. Estuarine, Coastal and Shelf Science, 95(1), 52-58.

Nedelec, H. & Verlaque, M. (1984). Alimentation de l'oursin *Paracentrotus lividus* (Lamarck) dans un herbier a Posidonia oceanica (L.) Delile n Corse (Mediterranee – France). In: Boudouresque CF, Jeudy de Grissac A,Olivier J (eds) International workshop on *Posidonia oceanica* beds. GIS Posidonie, Marseilles, pp 349–364.

Neill, F.X. & Pastor, R. (1973). Relaciones tróficas de *Paracentrotus lividus* (Lmk.) en la zona litoral. Investigation Pesquiera, 37 (1), 1–7

Neofitou, N., Charizopoulos, N., Vafidis, D., Skordas, K., Tziantziou, L. & Neofitou, C. (2014). Mussel farming impacts on trophic status and benthic community structure in Maliakos Gulf (Eastern Mediterranean). Aquaculture international, 22(2), 843-857.

Nikolic, V., Zuljevic, A., Mangialajo, L., Antolic, B., Kuspilic, G. & Ballesteros, E. (2013). Cartography of littoral rocky-shore communities (CARLIT) as a tool for ecological quality assessment of coastal waters in the Eastern Adriatic Sea. Ecological Indicators, 34, 87-93.

Nilsson, J., Engkvist R. & Persson, L. E. (1999). Restaurering av Kustvattenmiljöer. Restorations of Coastal Environments.Dnr (1699-2/95), (2063/96), Slutrapport 1996–1999, 1–17 (in Swedish).

Nilsson, J., Engkvist, R. & Persson, L. E. (2004). Long-term decline and recent recovery of *Fucus* populations along rocky shores of southeast Sweden, Baltic Sea. Aquatic Ecology 38, 587e598.

Okuda, K. (2008). Coastal environment and seaweed-bed ecology in Japan. Kuroshio Science, 2 (1), 15-20.

Olenin, S. & Klovaitơ, K. (1998). Introduction to the marine and coastal environment of Lithuania. In: Red list of marine and coastal biotopes and biotope complexes of the Baltic Sea, Belt Sea and Kattegat. Baltic Sea Environment Proceedings 75. HELCOM, Helsinki. pp 39-43.

Orfanidis, S., Panayotidis, P. & Ugland, K. (2011). Ecological Evaluation Index continuous formula (EEI-c) application: a step forward for functional groups, the formula and reference condition values. Mediterranean Marine Science, 12 (1), 199-232.

Orfanidis, S., Dencheva, K., Nakou, K., Tsioli, S., Papathanasiou, V. & Rosati, I. (2014). Benthic macrophyte metrics as bioindicators of water quality: towards overcoming typological boundaries and methodological tradition in Mediterranean and Black Seas. Hydrobiologia, 740 (1), 61-78.

Orlando-Bonaca, M., & Lipej, L. (2005). Factors affecting habitat occupancy of fish assemblage in the Gulf of Trieste (Northern Adriatic Sea). Marine Ecology, 26(1), 42-53.

Orlando-Bonaca, M., Lipej, L. & Orfanidis, S. (2008). Benthic macrophytes as a tool for delineating, monitoring and assessing ecological status: the case of Slovenian coastal waters. Marine Pollution Bulletin, 56(4), 666-676.

Orlando-Bonaca, M. & Mavric, B. (2014). Recurrence of *Sargassum vulgare* C. Agardh in Slovenian coastal waters (Adriatic sea) / Ricomparsa di *Sargassum vulgare* C. Agardh in acque costiere slovene (mare Adriatico). In Annales: Series Historia Naturalis (Vol. 24, No. 2, p. 109). Scientific and Research Center of the Republic of Slovenia.

Osservatorio turismo Campania (2007). (Available at http://www.ontit.it/opencms/opencms/ont/it/documenti/start.html?category=documenti/regioni/campania)

Panayotidis, P., Feretopoulou, J. & Montesanto, B. (1999). Benthic vegetation as an ecological quality descriptor in an Eastern Mediterranean coastal area (Kalloni Bay, Aegean Sea, Greece). Estuarine Coastal and Shelf Science, 48, 205-214.

Panayotidis, P., Montesanto, B. & Orfanidis, S. (2004). Use of low-budget monitoring of macroalgae to implement the European Water Framework Directive. Journal of Applied Phycology, 16, 49-59.

Pandolfi, J. M., Bradbury, R. H., Sala, E., Hughes, T. P., Bjorndal, K. A., Cooke, R. G. & Warner, R. R. (2003). Global trajectories of the long-term decline of coral reef ecosystems. Science, 301(5635), 955-958.

Pardi, G., Piazzi, L. & Cinelli, F. (2000). Demographic Study of a *Cystoseira humilis* Kuetzing (Fucales: Cystoseiraceae) population in the Western Mediterranean. Botanica Marina, 43(1), 81-86.

Parenzan, P. (1956). Biocenologia dei fondi marini a Zoosteracee. Bollettino di Zoologia, 23, 621-637.

Pauly, D. (1995). Anecdotes and the shifting baseline syndrome of fisheries. Trends in ecology and evolution, 10(10), 430.

Pavia, H., Carr, H. & Åberg, P. (1999). Habitat and feeding preferences of crustacean mesoherbivores inhabiting the brown seaweed *Ascophyllum nodosum* (L.) Le Jol.and its epiphytic macroalgae. Journal of Experimental Marine Biology and Ecology, 236, 15–32.

Pearson, G., Serrão, E. (2006). Revisiting synchronous gamete release by fucoid algae in the intertidal zone: fertilization success and beyond? Integrative and Comparative Biology, 46, 587–97.

Perkol-Finkel, S. & Airoldi, L. (2010). Loss and recovery potential of marine habitats: an experimental study of factors maintaining resilience in subtidal algal forests at the Adriatic Sea. Plos One, 5.

Perkol-Finkel, S., & Sella, I. (2014). Ecologically active concrete for coastal and marine infrastructure: innovative matrices and designs. In From Sea to Shore—Meeting the Challenges of the Sea (pp. 1139-49). London: ICE.

Piazzi, L., Balata, D., Ceccherelli, G. (2017). Resilience of *Cystoseira* beds: lack of canopy effects on recruitment. Botanica Marina, 60(1), 49-53.

Phillips, J. A. & Blackshaw, J. K. (2011). Extirpation of macroalgae (*Sargassum* spp.) on the subtropical east Australian coast. Conservation biology, 25(5), 913-921.

Pimm, S. L. & Raven, P. (2000). Biodiversity: Extinction by numbers. Nature, 403, 843-845.

Pinedo, S., Garcia, M., Satta, M. P., de Torres, M. & Ballesteros, E. (2007). Rocky-shore communities as indicators of water quality: a case study in the Northwestern Mediterranean. Marine Pollution Bulletin, 55, 126-135.

Pinedo, S., Arévalo, R. & Ballesteros, E. (2015). Seasonal dynamics of upper sublittoral assemblages on Mediterranean rocky shores along a eutrophication gradient. Estuarine, Coastal and Shelf Science, 161, 93-101.

Pitacco, V., Orlando-Bonaca, M., Mavric, B., Popovic, A. & Lipej, L. (2014). Mollusc fauna associated with the *Cystoseira* algal associations in the Gulf of Trieste (Northern Adriatic Sea). Mediterranean Marine Science, 15, 225-238.

Plinski, M. & Florczyk, I. (1984). Analysis of the composition and vertical distribution of the macroalgae in western part of the Gulf of Gdansk in 1979 and 1980. Oceanologia/Oceanology, 19, 101-116.

PNAT (2016). Variante al Piano del Parco Nazionale Arcipelago Toscano ex art. 12 L. 394/1991 - Nuova zonazione a mare dell'Isola di Capraia. Ente Parco Nazionale Arcipelago Toscano - NEMO, Firenze

Porzio, L. (2006). Valutazione dello stato ecologico delle acque costiere nel Golfo di Napoli attraverso l'utilizzo di macroalghe come elemento biologico di qualità. Master's Thesis.

Porzio, L., Buia, M. C. & Hall-Spencer, J. M. (2011). Effects of ocean acidification on macroalgal communities. Journal of Experimental Marine Biology and Ecology, 400(1), 278-287.

Porzio, L., Buia, M. C., Lorenti, M., De Maio, A., & Arena, C. (2017). Physiological responses of a population of *Sargassum vulgare* (Phaeophyceae) to high pCO 2/low pH: implications for its long-term distribution. Science of The Total Environment, 576, 917-925.

Prato, G., Guidetti, P., Bartolini, F., Mangialajo, L. & Francour, P. (2013). The importance of high-level predators in marine protected area management: Consequences of their decline and their potential recovery in the Mediterranean context. Advances in Oceanography and Limnology, 4(2), 176-193.

Procaccini, G., Buia, M. C., Gambi, M. C., Perez, M., Pergent, G., Pergent-Martini, C. & Romero, J. (2003). The Western Mediterranean. World atlas of seagrasses, 48.

Puccio, V., Relini, M., Azzurro, E., & Relini, L. O. (2006). Feeding habits of *Percnon gibbesi* (H. Milne Edwards, 1853) in the Sicily Strait. In: *Issues of Decapod Crustacean Biology* (pp. 79-84). Springer Netherlands.

Turk R.,Vukovic A., (1994). Preliminary inventory and topography of flora and fauna in the marine part of the Strunjan Nature Reserve, Ann. Ser. Hist. Nat. 4, pp. 101–112.

Ragan, C.M., Glombitza, K.W. (1986). Phlorotannins, brown algal polyphenols. Progress in Phycological Research, 4, 129-241.

Raybaud, V., Beaugrand, G., Goberville, E., Delebecq, G., Destombe, C., Valero, M., Davoult, D., Morin, P. & Gevaert, F. (2013). Decline in kelp in west Europe and climate. PloS One 8 (6), e66044.

Reed, D. C., Laur, D. R. & Ebeling, A. W. (1988). Variation in Algal Dispersal and Recruitment: The Importance of Episodic Events. Ecological Monographs, 58(4), pp. 321-335.

Reed, D. C., Ebeling, A. W., Anderson, T. W. & Anghera, M. (1996). Differential reproductive responses to fluctuating resources in two seaweeds with different reproductive strategies. Ecology 77:300–16

Reinke, J. (1878a). Cutleriaceen des Golfs von Neapel. Nova Acta der Ksl. Leop.-Carol.-Deutschen Akademie der Naturforscher. Band XL. 1: pp 45 + Tav.

Reinke, J., (1878b). Dictyotaceen des Golfs von Neapel. Nova Acta der ksl. Leop.-Carol.-Deutschen Akademie der Naturforscher. Band XL. 2: pp 25 + Tav.

Regione Campania (2014). Report Programma Interventi Available at http://www.regione.campania.it/assets/documents/report-gp-regi-lagni-definitivo-1.pdf

Ribera d'Alcalà, M., Modigh, M., Moretti, M., Saggiomo, V., Scardi, M., Spezie, G. & Zingone, A. (1989). Una storia infinita. Eutrofizzazione nella Baia di Napoli. Oebalia XV, 491-501.

Ribera d'Alcalà, M. & Russo, G. F. (2001). Studio di fattibilità propedeutico all'istituzione dell'Area Marina Protetta denominata "Isola di Capri". Relazione seconda fase. Ministero dell'Ambiente, Roma. Report SZN.

Ribera Siguan, M., Gomez Garreta, A., Gallardo, T., Cormaci, M., Furnari, G. & Giaccone, G. (1992). Checklist of Mediterranean seaweeds. 1. Fucophyceae Botanica Marina, 35 (2), 109-130.

Riccato, F., Fiorin, R., Curiel, D., Rismondo, A., Cerasuolo, C. & Torricelli, P. (2008). Interaction between fish and *Cystoseira* communities of artificial rocky shores in the Gulf of Venice. Bollettino del Museo Civico di Storia Naturale di Venezia, 59, 95-108.

Rindi, F., Battelli, C. (2005). Spatio-temporal variability of intertidal algal assemblages of the Slovenian coast (Gulf of Trieste, northern Adriatic Sea). Botanica Marina, 48(2), 96-105.

Rindi, F., Gavio, B., Romagnoli, T., Falace, A., Díaz-Tapia, P. (2016). New observations on the benthic algal flora of the area of Ancona. In: Riunione Scientifica Annuale del Gruppo di Lavoro per l'Algologia, Ravenna (RA) 18-19 novembre 2016, Abstract book.

Robvieux, P. (2013). Conservation des populations de *Cystoseira* en régions Provence-Alpes-Côte-d'Azur et Corse (Doctoral dissertation, Université Nice Sophia Antipolis).

Rochette, R., Hamel, J. F. & Himmelman, J. H. (1994). Foraging strategy of the asteroid *Leptasterias polaris*: role of prey odors, current and feeding status. Marine Ecology-Progress Series, 106, 93-93.

Rodríguez-Prieto, C. (1992). Estudi de l'estructura, la dinàmica i la fenologia de la comunitat de *Cystoseira mediterranea* Sauvageau: la importància de les minves d'hivern (Doctoral dissertation, Université de Barcelone).

Rodríguez Prieto, C. & Polo Albertí, L. (1996). Effects of the sewage pollution in the structure and dynamics of the community of *Cystoseira mediterranea* (Fucales, Phaeophyceae). Scientia marina, 60 (2-3), 253-263.

Rodríguez-Prieto, C., Ballesteros, E., Boisset, F. & Afonso-Carrillo, J. (2013). Guía de las macroalgas y fanerógamas marinas del Mediterráneo occidental. Omega, Barcelona.

Rosemarin, A., Mattsson, J., Lehtinen, K-J., Notini, M. & Nylén, E. (1986). Effects of pulp mill chlorate (ClO−3) on *Fucus vesiculosus* – a summary of projects. Ophelia, 4, 219–224.

Russell, B., Pollard, D., Mann, B.Q., Buxton, C.D. & Carpenter, K.E. (2014). *Sarpa salpa*. The IUCN Red List of Threatened Species 2014: e.T170169A1286510. http://dx.doi.org/10.2305/IUCN.UK.2014-3.RLTS.T170169A1286510.en. Downloaded on 03 September 2016

Russo, G. F., Di Donato R. & Di Stefano F. (2008). Gli habitat sottomarini delle coste della Campania. Biologi Italiani, 38(6), 36-86.

Saggiomo V., Buia M.C., (2005). Relazione Finale: Effetti degli agenti biotici marini sulla conservazione delle strutture archeologiche sommerse presenti nel Parco Marino di Gaiola (Golfo di Napoli).

Saggiomo V., Buia M.C., (2006). Relazione Finale: Effetti degli agenti biotici marini sulla conservazione delle strutture archeologiche sommerse presenti nel Parco Sommerso di Baia (Golfo di Napoli).

Saggiomo V., Catalano G., Corato F., Ribera D'Alcalà M. (2010). Metodi automatici di analisi dei nutrienti. In: Socal G., Buttino I., Cabrini M., Mangoni O., Penna A., Totti C. (eds.). Metodologie di studio del plancton marino, Manuali e Linee Guida 56/2010, ISPRA, SIBM Roma, 55-79.

Sala, E., Boudouresque, C. F. & Harmelin-Vivien, M. (1998). Fishing, trophic cascades, and the structure of algal assemblages: evaluation of an old but untested paradigm. Oikos, 425-439.

Sala, E., Ballesteros, E., Dendrinos, P., Di Franco, A., Ferretti, F., Foley, D., Fraschetti, S., Friedlander, A., Garrabou, J., Guclusoy, H., Guidetti, P., Halpern, B. S., Hereu, B., Karamanlidis, A.A., Kizilkaya, Z., Macpherson, E., Mangialajo, L., Mariani, S., Micheli, F., Pais, A., Riser, K., Rosenberg, A. A., Sales, M., Selkoe, K. A., Starr, R., Tomas, F. & Zabala, M., (2012). The structure of Mediterranean rocky reef ecosystems across environmental and human gradients, and conservation implications. Plos One 7.

Sales, M. & Ballesteros, E.. (2009). Shallow *Cystoseira* (Fucales: Ochrophyta) assemblages thriving in sheltered areas from Menorca (NW Mediterranean): Relationships with environmental factors and anthropogenic pressures. Estuarine Coastal and Shelf Science, 84, 476-482.

Sales, M., Cebrian, E., Tomas, F. & Ballesteros, E. (2011). Pollution impacts and recovery potential in three species of the genus *Cystoseira* (Fucales, Heterokontophyta). Estuarine, Coastal and Shelf Science, 92(3), 347-357.

Sales, M., Ballesteros, E., Anderson, M. J., Iveša, L. & Cardona, E. (2012). Biogeographical patterns of algal communities in the Mediterranean Sea: *Cystoseira crinita*-dominated assemblages as a case study. Journal of biogeography, 39(1), 140-152.

Sales, M., Ballesteros, E., Vidal, E., Tomas, F., Moranta, J., & Cebrian, E. (2015). New Method for Restoring Degraded *Cystoseira* Forests. In: European Journal Of Phycology (Vol. 50, Pp. 108-109). 4 Park Square, Milton Park, Abingdon Ox14 4rn, Oxon, England: Taylor & Francis Ltd.

Sauvageau, C., (1912). A propos des *Cystoseira* de Banyuls et de Gue´thary. Bull. de la Station Biologique d'Arcachon 14, 133–556.

Schiel, D. R. & Foster, M. S. (2006). The population biology of large brown seaweeds: ecological consequences of multiphase life histories in dynamic coastal environments. Annual Review of Ecology, Evolution, and Systematics, 343-372.

Schramm, W. (1996). The Baltic Sea and its transition zones. In Marine benthic vegetation, Nienhus (eds) Springer-Verlag, Berlin, Germany, 470 pp.

Scipione, M. B., Garrard, S. L. (2013). Can low pH values affect amphipod assemblages in *Posidonia oceanica* meadows? 15th International Colloquium on Amphipoda, 2-7 September 2013, Szczawnica (Poland): 91. Grabowski M., Rachalewski M. & Konopacka A. (Eds.), Drukarnia Cyfrowa i Wydawnictwo "Piktor" s.c., Łódź (Poland).

Scipione, M. B., Ricevuto, E. & Gambi, M. C. (2015). Amphipod assemblages in a CO2 volcanic vents system: a study from artificial collectors along a pH gradient. 16th International Colloquium on Amphipoda, 7-11 September 2015, Aveiro (Portugal): 84. Book of abstracts / coord. Filipe O. Costa, Marina R. Cunha. – Aveiro: UA Editora.

Sellimi, S., Kadri, N., Barragan-Montero, V., Laouer, H., Hajji, M. & Nasri, M. (2014). Fucans from a Tunisian brown seaweed *Cystoseira barbata*: Structural characteristics and antioxidant activity. International Journal of Biological Macromolecules, 66, 281-288.

Serisawa, Y., Imoto, Z., Ishikawa, T. & Ohno, M. (2004). Decline of the *Ecklonia cava* population associated with increased seawater temperatures in Tosa Bay, southern Japan. Fisheries Science, 70: 189–191.

Serrao, E. A., Pearson, G., Kautsky, L., & Brawley, S. H. (1996). Successful external fertilization in turbulent environments. Proceedings of the National Academy of Sciences, 93(11), 5286-5290.

Sfriso, A. & La Rocca, B. (2005). Aggiornamento sulle macroalghe presenti lungo i litorali e sui bassofondali della Laguna di Venezia. Lavori Società Veneziana di Scienze Naturali, 30, 45-56.

Sfriso, A., Marcomini, A., & Pavoni, B. (1987). Relationships between macroalgal biomass and nutrient concentrations in a hypertrophic area of the Venice Lagoon. Marine Environmental Research, 22(4), 297-312.

Sfriso, A., Facca, C. & Ghetti, P.F. (2009). Validation of the Macrophyte Quality Index (MaQI) set up to assess the ecological status of Italian marine transitional waters. Hydrobiologia, 617, 117-141.

Simboura, N., Panayotidis, P. & Papathanassiou, E. (2005) A synthesis of the biological quality elements for the implementation of the European Water Framework Directive in the Mediterranean ecoregion: the case of Saronikos Gulf. Ecological Indicators, 5, 253-266

Simeone, M., Russo, G. F. (2005). Il Parco Sommerso della Gaiola. In: Carrada G. C., Coiro P., Russo G. F. (eds), Le aree marine protette. I Quaderni di uomo e natura 2. Electa Napoli, 85-94.

Simeone, M., Cutugno, M., Psomadakis, P., Giustino, S., Sardo, A. & Masucci, P. (2010). Relazione tecnica sevizio ordinario di monitoraggio biologico ambinetale del parco sommerso di Gaiola. C.S.I. Gaiola onlus.

Simeone, M., Masucci, P., Usai, A., Giordano, D., De Vivo, C., Saccone, O., Moraca, M., Pagliarani, A., De Luca, G., Genovese, M. & Grech, D. (2016a). Technical report of MedPAN (Mediterranean Protected Areas Network) project "A territorial analysis for the integrated management of the Posillipo Coastline"- C.S.I. Gaiola onlus. (in press)

Simeone, M., Masucci, P., Usai, A., Giordano, D., De Vivo, C., Saccone, O., Grech, D., Pagliarani, A., De Luca, G., Genovese, M., Moraca, M., Tatino, F. & Truccolo, A. (2016b). Medpan

Project “Territorial Analysis For The Integrated Management Of The Posillipo Coastline” (Gulf Of Naples) Sesto Simposio "Il Monitoraggio Costiero Mediterraneo: problematiche e tecniche di misura". Livorno 28-29 settembre 2016.

Singleton, V. L. & Rossi, J. A. (1965). Colorimetry of total phenolics with phosphomolybdic-phosphotungstic acid reagents. American journal of Enology and Viticulture, 16(3), 144-158.

Smale, D. A. & Wernberg, T. (2013). Extreme climatic event drives range contraction of a habitat-forming species. In Proceeding of the Royal Society of London B (Vol. 280, No. 1754, Volume 280, issue 1754

Solms-Laubach, G. Z. (1881). Die Corallinenalgen des Golfes von Neapel und der Angrenzenden Meeres-Abschnitte. Eine Monographie. Herausgegeben von der Zoologischen Station Zu Neapel. 64pp + 3 Tavv.

Soltan, D., Verlaque, M., Boudouresque, C. F. & Francour, P. (2001). Changes in macroalgal communities in the vicinity of a Mediterranean sewage outfall after the setting up of a treatment plant. Marine Pollution Bulletin, 42 (1), 59–70.

Soria, A. & Buia, M. C. (2008). Historical changes in macroalgal diversity in the Gulf of Naples: from 1878 to 2007. World Conference on Marine Biodiversity, 11-15 November 2008, Valencia, Spain.

Soria, A. (2008), ALGAEBRA: A data warehouse management system to monitor macroalgal diversity in the Gulf of Naples, PhD Thesis, University of Messina, Messina, Italy.

Stekoll, M. S., Deysher, L., Highsmith, R. C., Saupe, S. M., Guo, Z., Erickson, W. P. & Strickland, D. (1996). Coastal habitat injury assessment: intertidal communities and the Exxon Valdez oil spill. In American Fisheries Society Symposium.

Steneck, R. S., Graham, M. H., Bourque, B. J., Corbett, D., Erlandson, J. M., Estes, J. A. & Tegner, M. J. (2002). Kelp forest ecosystems: biodiversity, stability, resilience and future. Environmental conservation, 29 (04), 436-459.

Strain, E., Thomson, R. J., Micheli, F., Mancuso, F. P., & Airoldi, L. (2014). Identifying the interacting roles of stressors in driving the global loss of canopy-forming to mat-forming algae in marine ecosystems. Global Change Biology, 20(11), 3300-3312.

Strain, E. M., van Belzen, J., van Dalen, J., Bouma, T. J. & Airoldi, L. (2015). Management of local stressors can improve the resilience of marine canopy algae to global stressors. PloS one, 10(3), e0120837.

Strong, J. A., Maggs, C. A., Johnson, M. P. (2009). The extent of grazing release from epiphytism for *Sargassum muticum* (Phaeophyceae) within the invaded range. . Journal of the Marine Biological Association of the United Kingdom, 89 (2), 303–314

Sumayaa, S. & Kavitha, K. (2015). Preparation of novel seaweed recipes and standardisation for the human consumption. International Journal, 3(10), 159-167.

Susini, M. L. (2006). Statut et biologie de *Cystoseira amentacea* var. *stricta* Ph.D. Thesis, Université de Nice-Sophia Antipolis, Nice.

Susini, M. L., Mangialajo, L., Thibaut, T. & Meinesz, A. (2007a). Development of a transplantation technique of *Cystoseira amentacea* var. *stricta* and *Cystoseira compressa*. Hydrobiologia, 580(1), 241-244.

Susini, M. L., Thibaut, T., Meinesz, A. & Forcioli, D. (2007b). A preliminary study of genetic diversity in *Cystoseira amentacea* (C. Agardh) Bory var. *stricta* Montagne (Fucales, Phaeophyceae) using random amplified polymorphic DNA. Phycologia, 46(6), 605-611.

Templado, J. (2014). Future trends of Mediterranean biodiversity. In “The Mediterranean Sea”, pp. 479-498, Springer Netherlands.

Abdala-Diaz, T. R., Cabello-Pasini, A., Marquez-Garrido, E. & Lopez Figueroa, F. (2014). Intra-thallus variation of phenolic compounds, antioxidant activity, and phenolsulphatase activity in *Cystoseira tamariscifolia* (Phaeophyceae) from southern Spain. Ciencias Marinas, 40:1-10.

Terawaki, T., Yoshikawa, K., Yoshida, G., Uchimura, M. & Iseki, K. (2003). Ecology and restoration techniques for *Sargassum* beds in the Seto Inland Sea, Japan. Marine Pollution Bulletin, 47(1), 198-201.

Tewari, A., & Joshi, H. V. (1988). Effect of domestic sewage and industrial effluents on biomass and species diversity of seaweeds. Botanica Marina, 31(5), 389-398.

Thibaut, T., Pinedo, S., Torras, X. & Ballesteros, E. (2005). Long-term decline of the populations of Fucales (*Cystoseira* spp. and *Sargassum* spp.) in the Alberes coast (France, North-western Mediterranean). Marine pollution bulletin,50 (12), 1472-1489.

Thibaut, T., Blanfune, A., Bottin, L., Markovic, L., Meinesz, A. & Robvieux, P. (2011). Evaluation of the fucales populations on the french Mediterranean coast. European Journal of Phycology, 46, 75-75.

Thibaut, T., Blanfune, A., Markovic, L., Verlaque, M., Boudouresque, C. F., Perret-Boudouresque, M., Macic, V. & Bottin, L. (2014). Unexpected abundance and long-term relative stability of the brown alga *Cystoseira amentacea*, hitherto regarded as a threatened species, in the north-western Mediterranean Sea. Marine Pollution Bulletin, 89, 305-323.

Thibaut, T., Blanfuné, A., Boudouresque, C. F. & Verlaque, M. (2015a) Decline and local extinction of Fucales in French Riviera: the harbinger of future extinctions?. Mediterranean marine science, 16(1), 206-224.

Thibaut, T., Blanfune, A., Boudouresque, C. F., Verlaque, M. (2015b). Loss of the habitat-forming *Cystoseira mediterranea* at its northern-limit of distribution in the Mediterranean sea. European Journal of Phycology, 50, 106-106.

Thibaut, T., Blanfuné, A., Verlaque, M., Boudouresque, C. F. & Ruitton, S. (2016a). The *Sargassum conundrum*: highly rare, threatened or locally extinct in the NW Mediterranean and still lacking protection. Hydrobiologia. Doi:10.1007/s10750-015-2580-y

Thibaut, T., Blanfuné, A., Boudouresque, C. F., Cottalorda, J. M., Hereu, B., Susini, M. L. & Verlaque, M. (2016b). Unexpected temporal stability of *Cystoseira* and *Sargassum* forests in Port-Cros, one of the oldest Mediterranean marine National Parks. Cryptogamie, Algologie, 37 (1), 61-90.

Thibaut, T., Bottin, L., Aurelle, D., Boudouresque, C. F., Blanfuné, A., Verlaque, M., Millet, B. (2016c). Connectivity of populations of the seaweed *Cystoseira amentacea* within the Bay of Marseille (Mediterranean Sea): genetic structure and hydrodynamic connections. Cryptogamie, Algologie.

Thiers, B. (2014). Index Herbariorum: A global directory of public herbaria and associated staff.New York Botanical Garden's Virtual Herbarium. http://sweetgum.nybg.org/ih/ (searchedon 10 September 2014).

Thiriet, P. (2014). Comparaison de la structure des peuplements de poissons et des processus écologiques sous-jacents, entre les forêts de Cystoseires et des habitats structurellement moins complexes, dans l'Infralittoral rocheux de Méditerranée nord-occidentale (Doctoral dissertation, Nice).

Thiriet P., Di Franco A., Cheminée A, Guidetti P, Bianchimani O, Basthard-Bogain S, Cottalorda J. M., Arceo H., Moranta J., Lejeune P., Francour P. & Mangialajo L. (2016). Abundance and diversity of crypto- and necto-benthic coastal fish are higher in marine forests than in structurally less complex macroalgal assemblages. PLoS One 11(10): e0164121.

Tina, G. (1994). Aspects écologiques d'un peuplement à *Cystoseira dubia* Valiante dans le circalittoral de Catane (Sicile orientale, Italie). Marine life, 4 (2), 9-17.

Tomas, F., Box, A. & Terrados, J. (2010). Effects of invasive seaweeds on feeding preference and performance of a keystone Mediterranean herbivore. Biological Invasions, 13(7), 1559-1570.

Tripodi, G. (1967). Fasce di vegetazione algale in alcune stazioni del Golfo di Napoli. Giornale Botanico Italiano, 73, 331-332.

Tsiamis, K., Panayotidis, P., Salomidi, M., Pavlidou, A., Kleinteich, J., Balanika, K. & Küpper, F. C. (2013). Macroalgal community response to re-oligotrophication in Saronikos Gulf. Marine Ecology Progress Series, 472, 73-85.

Tsiamis, K., Salomidi, M., Kytinou, E., Issaris, Y. & Gerakaris, V. (2016). On two new records of rare *Cystoseira taxa* (Fucales, Phaeophyceae) from Greece (Eastern Mediterranean). Botanica Marina, 59 (1), 73-77.

Tuya, F., Cacabelos, E., Duarte, P., Jacinto, D., Castro, J. J., Silva, T. & Wernberg, T. (2012). Patterns of landscape and assemblage structure along a latitudinal gradient in ocean climate. Marine Ecology Progress Series, 466, 9-19.

Underwood, A. J., Clarke, K. R. (2005). Solving some statistical problems in analyses of experiments on choices of food and on associations with habitat. Journal of Experimental Marine Biology and Ecology, 318, 227–237.

UNEP/MAP, (2005). Draft protocol on the integrated management of the Mediterranean coastal zones, Nice 2005.

Unimar (2010). PROGETTO P.E.S.C.A. Pesca Europea Servizi Cooperazione Ambiente - RACCOLTA DATI (Relazione finale)

Utilitas (2009). Final Report, Roma.

Uttieri, M., Cianelli, D., Nardelli, B. B., Buonocore, B., Falco, P., Colella, S. & Zambianchi, E. (2011). Multiplatform observation of the surface circulation in the Gulf of Naples (Southern Tyrrhenian Sea). Ocean Dynamics, 61(6), 779-796.

Underwood, A. J. (1997). Experiments in ecology: their logical design and interpretation using analysis of variance. Cambridge University Press.

Vadas, R., Wright, W. A., & Miller, S. L. (1990). Recruitment of *Ascophyllum nodosum*: wave action as a source of mortality. Marine Ecology-Progress Series, 61(3), 263-272.

Valiante, R. (1883). Le Cystoseirae del Golfo di Napoli. Fauna und Flora des Gofles von Neapel. 7, 1-30. (in italian).

Valls, A., Gascuel, D., Guénette, S. & Francour, P. (2012). Modeling trophic interactions to assess the effects of a marine protected area: case study in the NW Mediterranean Sea. Marine Ecology Progress Series, 456, 201-214.

Van Den Berg, H. A., Dann, S. L., & Dirkx, J. M. (2009). Motivations of adults for non-formal conservation education and volunteerism: Implications for programming. Applied Environmental Education and Communication, 8(1), 6-17.

Vaselli, S., Bulleri, F. & Benedetti-Cecchi, L. (2008). Hard coastal-defence structures as habitats for native and exotic rocky-bottom species. Marine Environmental Research, 66, 395-403.

Vasiliu, F., & Müller, G. I. (1973). Consequence of ice drift during the winter 1972/1973 on the *Cystoseira* populations along the Romanian shore of the Black Sea. Cercetari Marine-Recherches Marines, 5-6.

Velimirov, B. (1984). Grazing of *Sarpa salpa* L. on *Posidonia oceanica* and utilization of soluble compounds. In I International workshop on *Posidonia oceanica* beds. GIS Posidonie, Marseille, France, pp. 381-387.

Verges, A., Alcoverro, T. & Ballesteros, E. (2009). Role of fish herbivory in structuring the vertical distribution of canopy algae *Cystoseira* spp. in the Mediterranean Sea. Marine Ecology Progress Series, 375, 1-11.

Verges, A., Steinberg, P. D., Hay, M. E., Poore, A. G. B., Campbell, A. H., Ballesteros, E., Heck, K. L., Booth, D. J., Coleman, M. A., Feary, D. A., Figueira, W., Langlois, T., Marzinelli, E. M., Mizerek, T., Mumby, P. J., Nakamura, Y., Roughan, M., van Sebille, E., Sen Gupta, A., Smale, D. A., Tomas, F., Wernberg, T. & Wilson, S. K. (2014). The tropicalization of temperate marine ecosystems: climate-mediated changes in herbivory and community phase shifts. Proceedings of the Royal Society B-Biological Sciences, 281.

Verlaque, M. (1984). Biology of juveniles of the herbivorous sea-urchin, *Paracentrotus lividus* (Lamarck) - selectivity of grazing and impact on rocky algal communities in Corsica (Mediterranean, France). Botanica Marina, 27, 401-424.

Verlaque, M. (1987). Contributions à l'étude du phytobenthos d'un écosystème photophile thermophile marin en Méditerranée occidentale: étude structurale et dynamique du phytobenthos et analyse des relations faune-flore (Doctoral dissertation, Université d'Aix-Marseille II. Faculté des sciences).

Voerman, S. E., Llera, E. & Rico, J. M. (2013). Climate driven changes in subtidal kelp forest communities in NW Spain. Marine Environmental Research, 90, 119-127.

Vogt, H. & Schramm, W. (1991). Conspicuous decline of Fucus in Kiel Bay (western Baltic): What are the causes?. Marine Ecology Progress Series. Oldendorf, 69(1), 189-194.

Waern, M (1952). Rocky-shore algae in the Oeregrund archipelago. Acta phytogeogr suec 30: 1±298.

Watanuki, A., Aota, T., Otsuka, E., Kawai, T., Iwahashi, Y., Kuwahara, H. & Fujita, D. (2010). Restoration of kelp beds on an urchin barren: removal of sea urchins by citizen divers in southwestern Hokkaido. Bulletin of Fisheries Research Agency, 32, 83-87.

WFD, 2000 — Directive 2000/60/EC of the European Parliament and of the Council establishing a framework for the Community action in the field of water policy. Official journal of the european communities, 43 (L327): 1-73.

Whitaker, S. G., Smith, J. R. & Murray, S. N. (2010). Reestablishment of the Southern California rocky intertidal brown alga, *Silvetia compressa*: an experimental investigation of techniques and abiotic and biotic factors that affect restoration success. Restoration Ecology, 18 (1), 18-26.

Widdowson, T. (1971). Changes in the intertidal algal flora of the Los Angeles area since the survey by E. Yale Dawson in 1957-1959. Bull. S. Calif. Acad. Sci. 70: 2-16.

Worm, B., Lotze, H. K., Boström, C., Engkvist, R., Labanauskas, V. & Sommer, U. (1999). Marine diversity shift linked to interactions among grazers, nutrients and propagule banks. Marine Ecology Progress. Series, 185, 309–314.

Yu, Y. Q., Zhang, Q. S., Tang, Y. Z., Zhang, S. B., Lu, Z. C., Chu, S. H. & Tang, X. X. (2012). Establishment of intertidal seaweed beds of *Sargassum thunbergii* through habitat creation and germling seeding. Ecological Engineering, 44, 10-17.

Zaitsev, Y. & Mamaev, V. (1997). Marine biological diversity in the Black Sea. A study of change and decline. GEF Black Sea Environmental Series, 3, 208.

Zaitsev, Y. (2006). An Introduction on the Black Sea Ecology. Odessa: Even, 224 pp (in Russian).

Zingone, A., Montresor, M. & Marino, D. (1990). Summer phytoplankton physiognomy in coastal waters of the Gulf of Naples. Marine Ecology, 11(2), 157-172.

Zingone, A. & Buia, M. C. (2010). I siti LTER: il Golfo di Napoli, In: Bastianini, M., Buia, M. C., Cataletto, B., Fonda Umani, S., Lugliè, A. G. L., Marini, M Ravaioli, M. (2010). Lter, long term ecological research along the Italian coasts. Commission Internationale pour l'Exploitation Scientifique de la Mer Méditerranée: rapport du congrès, 39, 88.

Zingone, A., Dubroca, L., Iudicone, D., Margiotta, F., Corato, F., Ribera d'Alcalà, M., Saggiomo, V. & Sarno, D. (2010). Coastal phytoplankton do not rest in winter. Estuaries and Coasts, 33, 342-361.

Zucco, C. (2003). Evoluzione Urbanistico Territoriale delle Isole Flegree (Ischia Procida e Vivara", In: Gambi, M.C., de Lauro, M. and Iannuzzi, F. (Eds.), Ambiente marino costiero e territorio delle isole flegree (Ischia, Procida e Vivara, Golfo di Napoli), Memorie dell'Accademia di Scienze Fisiche e Matematiche. Napoli, 5, 303-396.

Zupo, V., Buia, M. C. (2000). Rapporto finale di attività: Ecologia della Pesca e gestione sperimentale dell'area a tutela biologica del Banco di Santa Croce (Golfo di Napoli). Programma di Ricerca finanziato dal Ministero per le Risorse Agricol, 395 pp.

Zupo, V., Buia, M. C., Gambi, M. C., Lorenti, M. & Procaccini, G. (2006a). Temporal variations in the spatial distribution of shoot density in a *Posidonia oceanica* meadow and patterns of genetic diversity. Marine Ecology, 27(4), 328-338.

Zupo, V., Mazzella, L., Buia, M. C., Gambi, M. C., Lorenti, M., Scipione, M. B. & Cancemi, G. (2006b). A small-scale analysis of the spatial structure of a *Posidonia oceanica* meadow off the Island of Ischia (Gulf of Naples, Italy): relationship with the seafloor morphology. Aquatic botany, 84(2), 101-109.

Annex I - HR Tables (T1-T20)

Historical records of Fucales (*Cystoseira* and *Sargassum* spp.) along the Gulf of Naples.
CR= Current Record after HR surveys. 0=Absent; +=Present; NI=Not Investigated; CI= Current; Var. = variety; CI= Current Identification for the HR gathered as *Cystoseira* sp. or *Sargassum* sp.

T1. *Cystoseira amentacea*

Year	Sector	Site	Depth	Reference	CR
1882	C	Posillipo	1-4 m	Herb. Uni. Roma-La Sapienza - legit Valiante, 1882	+
1898	C	San Giovanni a Teduccio	n.d.	Herb. Uni.Padova, M. Mazza, 1898	0
1903	B	Castello di Baia	n.d.	Mazza, 1903	0
1903	C	Portici	Shallow	Mazza, 1903	0
1903	C	San Giovanni a Teduccio	n.d.	Mazza, 1903	0
1927	A	Ischia north side (a lot of points showed in map by Funk)	1-2 m	Funk, 1927 map; Funk Diary	+
1927	A	Lava d'Arso	n.d.	Funk, 1927	0
1927	B	Bay of Miseno	0 m	Funk, 1927	+
1927	B	Grotta dei briganti (Posillipo close to Porto Rendell)	Shallow	Funk, 1927	+
1927	B	Capo Miseno (west side)	0,5 m	Funk, 1927	+
1927	B	Capo Miseno	0	Funk, 1927	0
1927	B	Miseno Grotto	Shallow	Funk, 1927	0
1927	B	Nisida lato nord	1 m	Funk, 1927	+
1927	B	Punta Pennata	30-40 m	Funk, 1927	0
1927	B	Punta Pennata	Shallow	Funk, 1927	0
1927	C	Badessa bank (the misunderstood Gaiola bank)	25-40 m	Funk, 1927	+
1927	C	Capo Posillipo	0.2 m	Funk, 1927	+
1927	C	Capo Posillipo	n.d, 0 m	Funk, 1927	0
1927	C	Gaiola	0.3 m	Funk, 1927	+
1927	C	Grotta del tuono (Posillipo) - Grotte di Trentaremi	Shallow	Funk, 1927	0
1927	C	Posillipo	10-11 m	Funk, 1927	+
1927	C	Rendell Harbour	2 m	Funk, 1927	0
1927	E	Marina Piccola	Shallow	Funk, 1927	0
1929	B	Rocce di San Martino	Shallow	Funk, 1927	0
1957	B	Nisida - Porto Paone	n.d.	Herbarium SZN (other collections): 9.9.1957	+
1957	C	Posillipo - Cala Garofano	n.d.	Herbarium SZN (other collections): 28-02-1957	0

1957	**C**	Posillipo - Baia Garofano	n.d.	Herbarium SZN (other collections): 9.9.1957	+
1957	**C**	Posillipo - Cala Garofano	n.d.	Herbarium SZN (other collections): 1.6.1957; 22.02.1957	+
1957	**D**	Capo di Sorrento	n.d.	Herbarium SZN (other collections): 8.8.1957	+
1959	**D**	Costa Sorrentina	0 m	Ernst, 1959 (in Riedl PSZN)	0
1962	**A**	Ischia - from Castello to P.ta San Pancrazio	4 m	Herbarium SZN (other collections): 8.8.1962	0
1962	**A**	Ischia - from Castello to P.ta San Pancrazio	4 m	Herbarium SZN (other collections): 8.8.1962	+
1962	**B**	Miseno	2 m	Herbarium SZN (other collections): 2-11.6.1962	+
1962	**C**	Capo Posillipo	n.d.	Herbarium SZN (other collections): 20.07.1962; 15.5.1969	0
1962	**C**	Trentaremi	n.d.	Herbarium SZN (other collections): 16.4-9?.1962	0
1963	**B**	Miseno grotto	n.d.	Herbarium SZN (other collections): 17.04.1963	0
1964	**C**	Posillipo - Villa Maista	n.d.	Herbarium SZN (other collections)	0
1968	**C**	Donnanna - Grotta Romana	Shallow	Herbarium SZN (other collections): 4.1968	0
1969	**C**	Capo Posillipo	n.d.	Herbarium SZN (other collections): 15.5.1969	+
1972	**D**	Cala di Mitigliano north side	n.d.	Feoli & Bressan 1972	0
1985	**A**	Ischia Rocce San Pietro	n.d.	Buia,1985 (pers. comm.)	0
1985	**D**	Punta del Capo	1 m	*CiSci Photo: Gargiulo E.(1985)*	0
1985	**D**	Serra Capriola	1 m	*CiSci Photo: Gargiulo E.(1985)*	0
2001	**E**	Arcera point	2-20 m	Ribera d'Alcalà & Russo, 2001	+
2001	**E**	Cala del Rio	n.d.	Ribera d'Alcalà & Russo, 2001	+
2001	**E**	Punta Carena	3-20 m	Ribera d'Alcalà & Russo, 2001	0
1909-1959	**A**	Lava d'Arso	0.5-2 m	Funk Diary	0
1909-1959	**B**	Capo Miseno	0.5-2 m	Funk Diary	0
1909-1959	**B**	Capo Miseno	0.5-2 m	Funk Diary	0
1909-1959	**C**	Capo Posillipo	10-11 m	Funk Diary	0
1909-1959	**C**	Marechiaro	1 m	Funk Diary	0
1990-2000	**D**	Punta del Capo	1 m	*CiSci Photo: Gargiulo*	0

T2. *Cystoseira barbata*

Year	Sector	Site	Depth	Reference	CR
1864	**A**	Ischia	n.d.	Herb. Uni. Padova (1864) C. Bolle	0
1879	**B**	Capo Coroglio	1-4 m	Falkenberg, 1879	0
1882	**C**	Posillipo	1-4 m, 4-7 m	Herb Roma-La Sapienza, legit Valiante,1881,1882	0
1927	**B**	Bacoli	5-8 m	Funk, 1927	0
1927	**B**	Castello di Baia	1.5-2 meters, 0.5 m	Funk, 1927	0
1927	**B**	Nisida lato nord	4-5 m	Funk, 1927	0

1927	**C**	Badessa bank (the misunderstood Gaiola bank)	25-40 m	Funk, 1927	0
1927	**C**	Capo Posillipo	Shallow	Funk, 1927	0
1927	**C**	Rendell Harbour	1 m	Funk, 1927; Herbarium SZN (other collections): 13.2.1957	0
1952	**B**	Capo Miseno	n.d.	Herbarium SZN (other collections) 2.6.1962	0
1954	**A**	Ischia Harbour	n.d.	Bonner (1954) Herb. SZN	0
1957	**B**	Capo Miseno	n.d.	Herbarium SZN (other collections): 12.2.1957; 2.6.1962	0
1957	**B**	Nisida - Porto Paone	n.d.	Herbarium SZN (other collections): 9.9.1957	0
1959	**D**	Costa Sorrentina	n.d.	Ernst, 1959	0
1961	**C**	Capo Posillipo	n.d.	Herbarium SZN (other collections):12.12.1961	0
1962	**C**	Posillipo - Villa Maista	n.d.	Herbarium SZN (other collections): 24.10.1962	0
1963	**C**	Trentaremi	n.d.	Herbarium SZN (other collections): 28303.1963, 6.7.1962	0
1968	**C**	Donnanna - Grotta Romana	n.d.	Herbarium SZN (other collections): 4.1968	0
1853-1936 †	**C**	Napoli	n.d.	Herb. Pirotta (HERB.Roma - La Sapienza)	0
1909-1959	**B**	Baoli (Bacoli)	5-8 m	Funk Diary	0
1909-1959	**C**	Marechiaro	1 m	Funk Diary	0
1909-1959	**C**	Napoli - Via Caracciolo	8-10 m	Funk Diary	0
1909-1959	**C**	Posillipo - Punta Cinita	6-8 m	Funk Diary	0

T3. *Cystoseira barbatula*

Year	Sector	Site	Depth	Reference	CR
1860	**C**	Napoli	n.d.	Kutzing, 1860 describing Sonder specimen herbaria	0

T4. *Cystoseira brachycarpa*

Year	Sector	Site	Depth	Reference	CR
1883	**E**	Capri	0-6-8 m	Valiante, 1883	+
1903	**B**	Bagnoli	n.d.	Mazza, 1903	0
1903	**B**	Baia	n.d.	Mazza, 1903	0
1903	**C**	Torre del Greco	n.d.	Mazza, 1903	0
1927	**A**	Ischia nord side	> 0.5 m	Funk, 1927 map, Funk Diary	0
1927	**A**	Ischia Rocce San Pietro	0.5 m	Funk, 1927 (1914)	0
1927	**A**	Lava d'Arso	n.d.	Funk, 1927	0
1927	**B**	Nisida nord side	4-5 m	Funk, 1927	0
1927	**C**	Badessa bank (the misunderstood Gaiola bank)	30-40 m, 30-49 m, 15-30 m	Funk, 1927, Funk Diary	0

1927	**C**	Posillipo	n.d.	Funk, 1927	0
1927	**D**	Banco di Bocca Piccola (the today called 'Secchetella shoal')	40-50 m	Funk, 1927	0
1927	**D**	Scoglio Vervece Bank Nord	30-40 m	Funk, 1927	0
1927	**E**	Marina Piccola	Shallow	Funk, 1927	+
1931	**B**	Rocce di San Martino	Shallow	Funk, 1927	0
1954	**A**	Rocce di S. Anna	n.d.	Bonner (1954) Herb. SZN	0
1971	**C**	Napoli	0-8 m	Herb. Giaccone (18.06.1971) in Catra e Grimaldi, 2003 Quad. Bot. Amb. Appl.	0
1972	**D**	Cala di Mitigliano	Shallow	Feoli & Bressan, 1972	0
1909-1959	**D**	Punta Campanella	30-50 m	Funk Diary	0

T5. *Cystoseira compressa*

Year	Sector	Site	Depth	Reference	CR
1838	**C**	Napoli	n.d.	Bonjean Botaniste, a Chambery (1838) Herb. Pirotta, Herb. Pedicino (HERB. Roma - La Sapienza)	0
1879	**C**	Posillipo	0.5 m	Falkenberg, 1879	+
1882	**C**	Posillipo	1-4 m	1882: Herb Roma-La Sapienza, legit Valiante	+
1898	**A**	Lacco Ameno	n.d.	luglio 1898, Micheletti HERB UniTo	0
1898	**C**	Portici	probably beaching	1898, racc. A. Mazza (Crittogame d'Italia in erbario L. Micheletti).HERB UNITO	0
1898	**C**	Torre del Greco	n.d.	Herb. Uni.Padova (1898)	0
1900	**C**	Torre del Greco	n.d.	Herb. Uni.Padova (1900)	0
1927	**A**	Ischia Harbour	1 m	Funk 1927; Cinelli et al. 1976a; Buia, 1985 (pers. comm.)	0
1927	**B**	Acquamorta (Maremorto)	n.d.	Funk, 1927	0
1927	**B**	Bacoli	5-8 m	Funk, 1927	0
1927	**B**	Banco di Biondo Palomba (the misunderstood Benta Palumbo)	n.d.	Funk, 1927	NI
1927	**B**	Castello di Baia	n.d.	Funk, 1927	0
1927	**B**	Capo Miseno	n.d.	Funk, 1927	+
1927	**B**	Capo Miseno	0	Funk, 1927	+
1927	**B**	Miseno Grotto	Shallow	Funk, 1927	+
1927	**B**	Nisida north side	1 (2-5) m	Funk, 1927	0
1927	**B**	Punta Pennata	0-2 m	Funk, 1927	+
1927	**B**	Punta Terore	n.d.	Funk, 1927	0
1927	**C**	Badessa bank (the misunderstood Gaiola bank)	25-40 m	Funk, 1927	0

1927	**C**	Capo Posillipo	0.5 m	Funk, 1927	+
1927	**C**	Castel dell'Ovo	n.d.	Funk, 1927	0
1927	**C**	Castel dell'Ovo	0.5 -3 m	Funk, 1927	0
1927	**C**	Castellammare	n.d. close to river mouth	Funk, 1927	0
1927	**C**	Grotta del tuono (Posillipo-Grotte di Trentaremi	n.d. 0.5 m	Funk, 1927	0
1927	**C**	Posillipo	n.d.	Funk, 1927	+
1927	**C**	Rendell Harbour	1 m	Funk, 1927	0
1927	**C**	Rocca Romana	sup.	Funk, 1927	0
1927	**D**	Sorrento	n.d.	Funk, 1927	0
1927	**E**	Marina Piccola	Shallow	Funk, 1927	+
1930	**B**	Rocce di San Martino	Shallow	Funk, 1927	0
1954	**A**	Rocce di S. Anna	n.d.	Bonner (1954) Herb. SZN	+
1957	**B**	Capo Miseno	n.d.	Herbarium SZN (other collections):15.03.1957 (Kusel o Beth?)	+
1957	**B**	Nisida - Porto Paone	n.d.	Herbarium SZN (other collections): 9.5.1957	0
1957	**D**	Capo di Sorrento	0.5-1 m	Funk Diary, Herbarium SZN (other collections): 8.8.1957	0
1959	**D**	Costa Sorrentina	n.d.	Ernst, 1959	+
1961	**C**	Capo Posillipo	n.d.	Herbarium SZN (other collections):12.12.1961	+
1962	**A**	Ischia - Casamicciola	n.d.	Herbarium SZN (other collections): 10.08.62 -	0
1962	**B**	Miseno	2 m	Herbarium SZN (other collections): 11.6.1962	+
1962	**C**	Capo Posillipo	n.d.	Herbarium SZN (other collections):18.05.1962, 12.12.1961; 15.5.1970-61	+
1962	**C**	Napoli-Mergellina	n.d.	Herbarium SZN (other collections): 29.01.1962	+
1963	**B**	Capo Miseno	n.d.	Herbarium SZN (other collections): 07.09.1963, 15.03.1957 (Kusel o Beth?)	+
1963	**B**	Miseno grotto	n.d.	Herbarium SZN (other collections): 17.04.1963	+
1963	**B**	Nisida - Porto Paone	n.d.	Herbarium SZN (other collections): 18.06.1963,22.05.1968;9.5.1957	0
1963	**C**	Posillipo - Villa Maista	n.d.	Herbarium SZN (other collections): 24.10.1962	0
1964	**C**	Trentaremi	n.d.	Herbarium SZN (other collections): 6.7.1962, 10.05.1962	+
1965	**B**	Nisida - Porto Paone	0-4 m	Gamulin-Brida, 1965	0
1968	**B**	Nisida - Porto Paone	n.d.	Herbarium SZN (other collections): 22.05.1968	0
1968	**C**	Donnanna - Grotta Romana	n.d.	Herbarium SZN (other collections): 4.1968	0
1968	**C**	Gaiola - Marechiaro	NI	Herbarium SZN (other collections): 16.6.1968	+
1970	**C**	Capo Posillipo	n.d.	Herbarium SZN (other collections):15.5.1970-61	+
1972	**D**	Cala di Mitigliano	n.d.	Feoli & Bressan, 1972	+
1977	**A**	Ischia Harbour	1 m	Funk, 1927; Cinelli et al., 1976a; Buia, 1985 (pers. comm.)	0
1985	**A**	Ischia Harbour	1 m	Funk, 1927; Cinelli et al., 1976a; Buia, 1985 (pers.	0

				comm.)	
1985	**D**	S. Fortunata	1 m	*CiSci Photo: Gargiulo E.(1985)*	0
1985	**D**	S. Fortunata	3 m	*CiSci Photo: Gargiulo E.(1985)*	0
1985	**D**	Punta Campanella	1 m	*CiSci Photo: Gargiulo E.(1985)*	0
1985	**D**	Serra Capriola	>5 m	*CiSci Photo: Gargiulo E.(1985)*	0
2001	**E**	Arcera point	2-20 m	Ribera d'Alcalà & Russo, 2001	0
2001	**E**	Punta Carena	3-20 m	Ribera d'Alcalà & Russo, 2001	0
1909-1959	**A**	Ischia Rocce San Pietro	0,5 m	Funk Diary	0
1909-1959	**B**	Baoli (Bacoli)	5-8 m	Funk Diary	0
1909-1959	**C**	Napoli - Via Caracciolo	5-10 m	Funk Diary	0
1909-1959	**C**	Posillipo - Punta Cinita	6-8 m	Funk Diary	0
1909-1959	**C**	Posillipo - Scogliera Manzi	0.5-1 m	Funk Diary	0
1990-2000	**D**	Punta del Capo	1 m	*CiSci Photo: Gargiulo*	0
1990-2000	**D**	Serra Capriola	~ 3 m	*CiSci Photo: Gargiul*	0
1967	**A**	Procida Solchiaro Inner side	0-2 m	Gamulin-Brida et al. 1967	0
1976	**A**	Vivara	Shallow	Cinelli et al. 1976b in Porzio T. 2006	+
1962	**A**	Ischia - from the Harbour to Lacco Ameno	1 m	Herbarium SZN (other collections): 8.8.1962 -	0

T6. *Cystoseira crinita*

Year	Sector	Site	Depth	Reference	CR
1879	**D**	Massa Lubrense	Shallow	Falkelberg, 1879	0
1972	**D**	Cala di Mitigliano	Shallow	Feoli & Bressan, 1972	0
1976	**A**	Vivara	below CA e CC, up to7-10 m	Cinelli et al., 1976b	0
1962	**A**	Ischia - from the Harbour to Lacco Ameno	1 m	Herbarium SZN (other collections): 7.8.1969	0
1962	**A**	Ischia - from the Harbour to Lacco Ameno	1 m	Herbarium SZN (other collections): 8.8.1962	0

T7. *Cystoseira dubia*

Year	Sector	Site	Depth	Reference	CR
1888	**B**	Banco di Biondo Palomba (the misunderstood Benta Palumbo)	60 m	Valiante, 1888;	NI
1927	**B**	Banco di Biondo Palomba (the misunderstood Benta Palumbo)	40 m	Funk, 1927	NI
1927	**C**	Torre Annunziata Bank	40 m, 35 m	Funk, 1927; Funk Diary	0
1927	**E**	Punta Carena	70 m	Funk, 1927	0
1971	**A**	Punta S. Pancrazio	40 m	Cinelli, 1971	0

1913-1927	**A**	Punta S. Angelo	50-70 m;	Funk (1913) Herb. SZN ; Funk, 1927	0
1913-1927	**A**	Punta S. Angelo	30-70 m; 50-100 m; 50-70 m	Funk, 1927; Funk ,1913 Herb. SZN; Funk Diary	0

T8. *Cystoseira foeniculacea*

Year	Sector	Site	Depth	Reference	CR
1789	**B**	Gulf of Baia	n.d.; 1-5 m;	Falkenberg, 1879; Funk 1927	0
1829	**B**	Baia	n.d.	Delle Chiaje, 1829	0
1879	**B**	Posillipo	n.d.	Falkenberg, 1879	0
1879	**C**	Posillipo - Palazzo Manzi	5-7 m, 7-10 m	Funk 1927; Falkenber, 1879	0
1898	**B**	Arco Felice	n.d.	Herb. Uni.Padova (1898)	0
1903	**B**	Arco Felice	n.d.	Mazza, 1903	0
1903	**B**	Miseno	n.d.	Mazza, 1903	0
1903	**C**	Torre del Greco	n.d.	Mazza, 1903Herb.Uni Padova (1898)	0
1927	**B**	Castello di Baia	1.5-2 metri	Funk,1927	0
1927	**B**	Gulf of Baia	3-4 m	Funk,1927	0
1927	**B**	Nisida lato nord	4-5 m	Funk,1927	0
1927	**C**	Badessa bank (the misunderstood Gaiola bank)	30-40 m,30-49 m; 20-15 m	Funk,1927	0
1927	**C**	Capo Posillipo	5-7; 7-10; 10-11 m ; 14-16 m	Funk,1927	0
1927	**D**	Scoglio Vervece Bank Nord	30-40 m	Funk,1927	0
1957	**C**	Posillipo - Cala Garofano	n.d.	Herbarium SZN (other collections): 22.02.1957	0
1957	**E**	Capri	n.d.	Herbarium SZN (other collections): 28.07.1957	+
1959	**D**	Costa Sorrentina	n.d.	Ernst, 1959	0
1959	**D**	Penisola sorrentina	1-2-3-15 m	Ernst, 1959	0
1959	**D**	Punta di Massa Marina di Puolo	1-2-3-15 m	Ernst, 1959	0
1959	**D**	Punta di Sorrento and Sorrento	1 m	Ernst, 1959	0
1959	**D**	Punta di Sorrento and Sorrento	2-3-15 m	Ernst, 1959	0
1961	**C**	Capo Posillipo	n.d.	Herbarium SZN (other collections): 12.12.1961	0
1961	**C**	Posillipo	n.d.	Herbarium SZN (other collections): 11.12.1961; Falkenberg, 1879	0
1962	**B**	Capo Miseno	20 m	Herbarium SZN (other collections): 24.5.1962	0
1967	**C**	Capo Posillipo	10-11 m ; 14-16 m	Gamulin-Brida et al., 1967	0
1967	**A**	Procida Solchiaro Inner side	6-10-22 m	Gamulin-Brida et al., 1967	0
1968	**C**	Donnanna - Grotta Romana	n.d.	Herbarium SZN (other collections): 4.1968	0
1909-1959	**C**	Posillipo Palazzo Volpicelli	0.5-1 m	Funk Diary	0
1909-1959	**D**	Scoglio Vervece Bank	15-30 m	Funk Diary	0

T9. *Cystoseira funkii*

Year	Sector	Site	Depth	Reference	CR
1976	**D**	Scoglio Vervece	25 m	Gerloff & Nizzamuddin 1976: 12.06.1924 Holotype herb Mus. Hist. Nat. Vindobon	0

T10. *Cystoseira mediterranea*

Year	Sector	Site	Depth	Reference	CR
1927	**C**	Grotta del tuono (Posillipo - Grotte di Trentaremi)	n.d.	Funk, 1927	0
1954	**A**	Rocce di S. Anna	n.d.	Bonner ,1954 -Herb. SZN	+
1957	**B**	Capo Miseno	n.d.	Herbarium SZN (other collections): 22.2.1957	0
1957	**D**	Capo di Sorrento	0.5	Funk Diary, Herbarium SZN (other collections):8.8.1957	0
1967	**A**	Procida Solchiaro Inner side	0-2 m	Gamulin-Brida et al., 1967	0
1967	**C**	between Torre del Greco and Torre Annunziata	1-2 m	Tripodi (1967)a	0
1968	**C**	Posillipo-Marechiaro	n.d.	Herbarium SZN (other collections): 16.06.1968	+
1974	**C**	Posillipo	n.d.	Carrada et al., 1974	+
1976	**A**	Vivara	Shallow	Cinelli et al., 1976b	0
1977	**A**	Ischia Harbour	n.d.	Cinelli et al., 1977a,b	0
1909-1959	**A**	Lava d'Arso	0.5-1 m	Funk Diary	0
1909-1959	**B**	Grotta dei Briganti (Posillipo close to Porto Rendell)	1 m	Funk Diary	0
1909-1959	**B**	Grotta di Miseno	0,5 m	Funk Diary	0
1909-1959	**B**	Rocce di San Martino	0 m	Funk Diary	0
1909-1959	**C**	Posillipo - Punta Cinita	6-8 m	Funk Diary	0
1909-1959	**C**	Posillipo - Scogliera Manzi	0.5	Funk Diary	+
1909-1959	**C**	Rendell Harbour	1 m	Funk Diary	0

T11. *Cystoseira sauvageauana*

Year	Sector	Site	Depth	Reference	CR
1882	**C**	Posillipo	2-30 m	1882: Herb Roma-La Sapienza, legit Valiante	0
1888	**B**	Capo Miseno	Deep	Valiante , 1883- 1888	0
1888	**B**	Nisida	Deep	Valiante, 1888: declivio di Nisida	0
1888	**C**	Badessa bank (the misunderstood Gaiola bank)	30-40 m; 25-40 m	Valiante, 1888;	0
1927	**C**	Badessa bank (the misunderstood Gaiola bank)	25-40 m	Funk, 1927	0
1955	**C**	Badessa bank (the misunderstood Gaiola bank)	25-40 m	Funk, 1955	0
1957	**E**	Capri	n.d.	Herbarium SZN (other collections): 28.7.1957	+
1909-1959	**B**	Punta Pennata	n.d.	Funk Diary	0

T12. *Cystoseira sedoides*

Year	Sector	Site	Depth	Reference	CR
1829	**B**	Golfo di Pozzuoli		Delle Chiaje, 1829	0

T13. *Cystoseira spinosa*

Year	Sector	Site	Depth	Reference	CR	var.
1883	**B**	Banco di Biondo Palomba (the misunderstood Benta Palumbo)	Deep	Valiante, 1883	NI	CSs
1883	**C**	Badessa bank (the misunderstood Gaiola bank)	30-49 m	Valiante, 1883	0	CSc
1883	**D**	Punta Campanella	Deep	Valiante, 1883	+	CSc
1927	**A**	Forio Bank	40 m	Funk, 1927	0	CSs
1927	**B**	Banco di Biondo Palomba (the misunderstood Benta Palumbo)	40-60 m	Funk, 1927	0	CSc
1927	**B**	Capo Miseno	8-15 m	Funk, 1927	0	CSs
1927	**B**	Punta Pennata	30- 40-50 m , n.d. 70 m	Funk Diary; Funk, 1927	0	CSc
1927	**C**	Badessa bank (the misunderstood Gaiola bank)	25-40 m; 25-30 m; 30-49 m	Funk, 1927, 1955, Herb SZN; Valiante, 1883	0	CSs
1927	**C**	Posillipo - Palazzo Manzi	6-8 m	Funk, 1927	0	CSc
1927	**C**	Banco di S. Giovanni a Teduccio (Secca del Campanile)	15 m	Funk, 1927; Cognetti & Santarelli, 1960	0	CSc
1927	**D**	Banco di Bocca Piccola (La Secchetella)	40-50 m, 90 m	Funk, 1927; Funk Diary	0	CSc
1927	**D**	Scoglio Vervece Bank	50 m	Funk, 1927	0	CSc
1927	**D**	Scoglio Vervece Bank - West	40 m	Funk, 1927	+	CSc
1927	**D**	Scoglio Vervece Bank - South	50 m	Funk, 1927	0	CSc
1927	**D**	Scoglio Vervece Bank North	30-40 m	Funk, 1927	0	CSc
1927	**D**	Scoglio Vervece Bank S-O	?-15; 30-40 m	Funk Diary, Funk, 1927	+	CSc
1927	**E**	Blue Grotto, close to	50 m, 30-50 m	Funk, 1927; Funk Diary	0	CSs
1955	**C**	Badessa bank (the misunderstood Gaiola bank)	25-30 m	Funk, 1955	0	CSc
1957	**E**	Capri	n.d.	Herbarium SZN (other collections)	+	Csc
1959	**D**	Baia di Ciercio	2-4 m	Ernst, 1959	0	Csc
1959	**D**	Punta di Massa	2-4 m	Ernst, 1959	0	Csc
1959	**D**	tra Punta di Sorrento e Sorrento	2-4 m	Ernst, 1959	0	CSc
1960	**A**	Banco di Forio	45-50 m	19.7.1960 SZN samples in Rupert Riedl Room	0	CSc

1960	**C**	Banco di San Giovanni a Teduccio (Secca del Campanile)	15 m	Cognetti & Santarelli, 1960	0	CSc
1971	**A**	Punta S. Pancrazio	45 m	Cinelli, 1971	0	CSc
1909-1958	**A**	Ischia Bank	40-50 m	Funk Diary	0	CSc
1909-1959	**B**	Gulf of Baia	0.5 m	Funk Diary	0	Csc
1909-1959	**B**	Miseno Grotto	12-25 m	Funk Diary	0	CSc
1909-1959	**C**	Posillipo (Cala Cinita)	6-8 m	Funk Diary	0	Csc
1882	**C**	Posillipo	1-4 m	Herb Roma-La Sapienza 1882, legit Valiante, Valiante, 1883;	0	Css
1883	**B**	Nisida	below to 7-8 m	Valiante, 1883	0	CSs
1883	**C**	Badessa bank (the misunderstood Gaiola bank)	0-35 m	Valiante, 1883	0	CSs
1883	**C**	Santa Lucia	fino a 7-8 m	Valiante, 1883	0	CSs
1927	**A**	Forio Bank	40 m	Funk, 1927	0	CSc
1927	**B**	Bacoli	5-8 m	Funk, 1927	0	CSs
1927	**B**	Capo Miseno (lato est)	0.5 m	Funk, 1927	0	CSs
1927	**C**	Posillipo	7-10 m	Funk, 1927	0	CSs
1927	**C**	Posillipo	n.d.	Funk, 1927	0	CSs
1927	**E**	Marina Piccola	sotto la superficie	Funk, 1927	0	CSs
1957	**B**	Capo Miseno	n.d.	Herbarium SZN (other collections)	0	CSs
1962	**A**	Ischia - from Castello to P.ta San Pancrazio	4 m	Herbarium SZN (other collections)	0	CSs
1971	**A**	Punta S. Pancrazio	45 m	Cinelli, 1971	0	CSc
1909-1959	**A**	Ischia Bank	40-50 m	Funk Diary	0	CSs
1909-1959	**B**	Baoli (Bacoli)	5-8 m	Funk Diary	0	CSs
1909-1959	**B**	Castello di Baia	0.5 m	Funk Diary	0	CSs
1971	**B**	S. Pancrazio	40 m	Cinelli, 1971	1	CSs
1909-1959	**B**	Capo Miseno	0.5-2 m	Funk Diary	0	CSs
1909-1959	**C**	Capo Posillipo	7-10 m	Funk Diary	0	CSs
1909-1959	**E**	Blue Grotto (close to)	50 m	Funk Diary	0	CSc
1962	**A**	Ischia - from Castello to P.ta San Pancrazio	4 m	Herbarium SZN (other collections)	0	CSs

1957	**B**	Capo Miseno	n.d.	Herbarium SZN (other collections)	0	CSt

T14. *Cystoseira tamariscifolia*

Year	Sector	Site	Depth	Reference	CR
1829	**A**	"Pytecusano litore" (Ischia)	Shallow	Delle Chiaje, 1829	0
1829	**C**	Gaiola ("Caiola")	Shallow	Delle Chiaje, 1829	0
1864	**A**	Castello d'ischia	n.d.	Herb. Uni.Padova, 1864) C. Bolle	0
1879	**B**	Miseno	0 m	Falkenberg, 1879	0
1879	**B**	Nisida	0 m	Falkenberg, 1879	0
1879	**B**	Punta Pennata	n.d.	Falkenberg, 1879	0
1879	**C**	Gaiola	0 m	Falkenberg, 1879	0
1898	**C**	Portici - Granatello beach	probably beaching specimens	A. Mazza (Crittogame d'Italia in erbario Micheletti) HERB UNITO spiaggia di Granatello, 27 marzo 1898, racc.	0
1853-1936 †	**C**	Napoli	n.d.	Herb. Pirotta (HERB.Roma - La Sapienza)	0
1909-1959	**B**	Nisida lato nord	4-5 m	Funk Diary	0
1909-1959	**B**	Rocce di San Martino	0 m	Funk Diary	0

T15. *Cystoseira zosteroides*

Year	Sector	Site	Depth	Reference	CR
1909-1959	**C**	Badessa bank (the misunderstood Gaiola bank)	25-30 m	Funk Diary	0
1879	**B**	Banco di Biondo Palomba (the misunderstood Benta Palumbo)	70 m	Falkenberg, 1879	NI
1879	**D**	Massa Lubrense	40-80 m	Falkelberg, 1879; Valiante, 1883	NI
1879	**E**	Capri	40-80 m	Falkelberg, 1879	0
1883	**B**	Banco di Biondo Palomba (the misunderstood Benta Palumbo)	40-70 m, 70 m, 40-80 m	Valiante, 1883	NI
1883	**C**	Santa Lucia	4-7 m	Valiante, 1883	0
1883	**D**	Massa Lubrense	n.d.	Valiante, 1883	NI
1883	**E**	Massa, presso Capri	acque profonde	Valiante, 1883	0
1903	**C**	Portici	n.d.	Mazza, 1903	0
1927	**B**	Banco di Biondo Palomba (the misunderstood Benta Palumbo)	40-80 m	Funk, 1927	NI
1927	**C**	Banco di San Giovanni a Teduccio (Secca del Campanile)	15-25 m 15-18 m	Funk, 1927; Funk Diary	0
1927	**E**	Blue Grotto, close to	70 m	Funk, 1927	NI
1957	**E**	Capri	n.d.	Herbarium SZN (other collections): 28.07.1957	0
1960	**A**	Forio Bank	45-50 m	19.7.1960 SZN samples in the Rupert Riedl Room	0
1971	**A**	Punta S. Angelo	15-50 m	Cinelli, 1971	1
1909-1959	**E**	Capri, nord side	50-70 m	Funk Diary	0

T16. *Cystoseira* sp.

Year	Sector	Site	Depth	Reference	CR	CI
1927	**B**	Nisida	n.d.	Funk, 1927	0	
1927	**C**	banci di Vico Equense (Banco di S. Croce)	20-40 m	Funk, 1927	+	
1965	**B**	Nisida - Porto Paone	2-3 m	Gamulin-Brida, 1965	0	
1985	**D**	Baia di Puolo	Shallow	*MAP CiSci project: Gargiulo E. & R. map and photo*	0	
1985	**D**	Cala di Mitigliano	n.d.	*CiSci project: Alba Sgambati*	+	CC
1985	**D**	Le Fontane-Punta Sorrentina	Shallow	*MAP CiSci project: Gargiulo E. & R. map and photo*	+	CC
1985	**D**	Marina Grande di Sorrento - Lato sx	Shallow	*MAP CiSci project: Gargiulo E. & R. map and photo*	0	
1985	**D**	Puntta Gradelle - Capo a dx di sorrento	Shallow	*MAP CiSci project: Gargiulo E. & R. map and photo*	0	

1985	**D**	Punta Corbo - Punta Sorrentina	Shallow	*MAP CiSci project: Gargiulo E. & R. map and photo*	+	CC/CA
1985	**D**	Punta del Capo	>5 m	*CiSci Photo: Gargiulo E.(1985)*	0	
1985	**D**	Punta S. Lorenzo	Shallow	*MAP CiSci project: Gargiulo E. & R. map and photo*	0	
1985	**D**	S. Liberatore - Punta Sorrentina	Shallow	*MAP CiSci project: Gargiulo E. & R. map and photo*	+	CC/CA
2000	**A**	Formiche di Vivara	5 m	Gambi et al., 2000	+	CC
2000	**C**	Gaiola -Tavola di Mare	Shallow	Simeone (pers. comm.)	+	CC
2001	**E**	Cala del Rio	n.d.	Ribera d'Alcalà & Russo, 2001	NI	
2001	**E**	Grotta dei Mandri (Bagno Tiberio - Punta Trasete	n.d.	Ribera d'Alcalà & Russo, 2001	NI	
2001	**E**	Grotta Verde	1-10 m	Ribera d'Alcalà & Russo, 2001	NI	
2001	**E**	Grotta Verde	n.d.	Ribera d'Alcalà & Russo, 2001	NI	
2001	**E**	Punta Carena South side	n.d.	Ribera d'Alcalà & Russo, 2001	NI	
2001	**E**	Punta del Fucile	3-15 m	Ribera d'Alcalà & Russo, 2001	0	
2001	**E**	Punta di Mulo	1-5 m	Ribera d'Alcalà & Russo, 2001	NI	
2001	**E**	Punta Marmolata	1-10 m	Ribera d'Alcalà & Russo, 2001	NI	
2001	**E**	Punta Trasete	3-10 m	Ribera d'Alcalà & Russo, 2001	+	
2001	**E**	Punta Ventroso - Scoglio di Marcellino	1-7 m	Ribera d'Alcalà & Russo, 2001	NI	
2001	**E**	Scoglio del Monacone	3-20 m	Ribera d'Alcalà & Russo, 2001	0	
2001	**E**	Punta del Capo - Scoglio della Ricotta	1-12 m	Ribera d'Alcalà & Russo, 2001	0	
2001	**E**	Punta trasete - Grotta dell'acqua	20 m	Ribera d'Alcalà & Russo, 2001	NI	CA
2004	**C**	Gaiola - Marechiaro	Shallow	Pagliarani, 2004	+	CA
2004	**C**	Gaiola - Rocce verdi	Shallow	Pagliarani, 2004	+	CA
2004	**C**	Gaiola - Trentaremi Coroglio	Shallow	Pagliarani, 2004	0	
2005	**C**	Gaiola	Shallow	Russo & Carrada, 2005	0	
2007	**A**	Casamicciola davanti al Pio Monte della Misericordia	0.5 m	ARPAC, 2007 Monitoraggio Acque/Ostreopsis	0	
2007	**C**	Capo Posillipo	0.5 m	ARPAC, 2007 Monitoraggio Acque/Ostreopsis	0	
2007	**C**	Capo Trentaremi	0.5 m	ARPAC, 2007 Monitoraggio Acque/Ostreopsis	0	

T17. *Sargassum acinarium*

Year	Sector	Site	Depth	Reference	CR
1829	**B**	Baia	n.d.	Delle Chiaje, 1829, Mazza, 1903	0
1879	**B**	Baia	Baia , comune	Falkenberg, 1879	0

1879	**C**	Posillipo	n.d.	Falkenberg, 1879	0
1898	**A**	Lacco Ameno		Micheletti S. linifolium (Turn) Lacco Ameno (Isola d'Ischia), luglio 1898 (Crittogame d'Italia in erbario Micheletti).	0
1898	**A**	Ischia	n.d.	Herb. Uni. Padova (1898) L. Micheletti (Crittogame d'italia)	0
1898	**C**	Portici	n.d	Herb. Uni. Padova (1898), Mazza, 1903	0
1903	**C**	Portici		Mazza, 1903	
1927	**A**	Ischia Harbour	n.d.	Funk, 1927	0
1927	**B**	Rocce di San Martino	Shallow	Funk 1927	0
1927	**C**	Castel dell'Ovo	0.5 -3 m	Funk, 1927	0
1927	**C**	Grotta del tuono (Posillipo - Grotte di Trentaremi)	n.d. , 0.5 m	Funk, 1927	0
1927	**C**	Rendell Harbour	1 m	Funk, 1927	0
1927	**C**	Capo Posillipo	0.5 m	Funk, 1927	0
1928	**B**	Punta Terore - Miseno	n.d.	Funk, 1927	0
1954	**A**	Ischia Rocce San Pietro	n.d.	Bonner, 1954, Herb. SZN	0
1957	**C**	Santa Lucia	n.d.	Herbarium SZN (other collections)	0
1957	**D**	Capo di Sorrento	n.d.	Herbarium SZN (other collections)	0
1957	**E**	Capri	n.d.	Herbarium SZN (other collections)	0
1961	**C**	Capo Posillipo	n.d.	Herbarium SZN (other collections)	0
1967	**A**	Procida Solchiaro Inner side	6-10-22 m	Gamulin-Brida et al., 1967	0
1968	**C**	Donnanna - Grotta Romana	n.d.	Herbarium SZN (other collections)	0
2015	**D**	Baia di Puolo - Penisola sorrentina	35 m	*CiSci Photo:Ruspantini E. (2015)*	0
1820-1897†	**C**	Portici	n.d.	(Turn) Ag., Portici bei Neapel gef. von [? ?] Martens (Rabenhorst Algen Europa's in erbario Gennari).	0
1830-1887†	**C**	Portici	n.d.	(Turn) Ag., Portici bei Neapel gef. Von [? ?] Martens (Rabenhorst Algen Europa's in erbario M. Malinverni) 10.	
1909-1959	**B**	Gulf of Baia	n.d.	Funk Diary	0

T18. *Sargassum hornschuchii*

Year	Sector	Site	Depth	Reference	CR
1829	**C**	Ercolano	n.d. probably beached specimen	Delle Chiaje,1829	0
1879	**E**	Capri	n.d.	Falkenberg, 1879	0
1894	**C**	Napoli	n.d.	Klein, 1894 in Herb. SZN	0
1903	**C**	Torre del Greco	n.d.	Mazza, 1903	0

1911	**A**	Procida	n.d	Leick, 1911 in Herb. SZN	0
1911	**B**	Miseno	n.d	Leick, 1911 in Herb. SZN	0
1912	**B**	Banco di Biondo Palomba (the misunderstood Benta Palumbo)	n.d.	Funk, 1912 Herb. SZN	NI
1927	**A**	Procida	n.d.	Funk, 1927	0
1927	**B**	Banco di Biondo Palomba (the misunderstood Benta Palumbo)	n.d.	Funk, 1927	NI
1927	**D**	Banco di Bocca Piccola (La Secchetella)	n.d.	Funk, 1927	0
1927	**D**	Scoglio Vervece Bank	50 m	Funk, 1927	1
1927	**D**	Scoglio Vervece Bank - West	40 m	Funk, 1927	0
1927	**D**	Scoglio Vervece Bank Nord	30-40 m	Funk, 1927	0
1927	**D**	Scoglio Vervece Bank S-O	30-40 m	Funk, 1927	0
1927	**E**	Blue Grotto, close to	50 m	Funk, 1927	0
1927	**E**	Punta Carena	n.d.	Funk, 1927	0
1954	**B**	Banco di Biondo Palomba (the misunderstood Benta Palumbo)	n.d.	Parenzan, 1956	NI
1957	**D**	Capo di Sorrento	n.d.	Herbarium SZN (other collections)	0
1957	**E**	Capri	50-80 m	Herbarium SZN (other collections); Falkenberg, 1879	0
1963	**C**	Capo Posillipo	n.d.	Herbarium SZN (other collections)	0
1971	**A**	Punta S. Angelo	30 m	Cinelli, 1971	0
1972	**D**	Cala di Mitigliano	n.d	Feoli & Bressan, 1972	0
2000	**C**	Banco di S. Croce	11 m	Zupo & Buia, 2000	0
1909-1959	**E**	Capri north side	50-70 m	Funk Diary	NI

T19. *Sargassum vulgare*

Year	Sector	Site	Depth	Reference	CR
1829	**C**	Gaiola ("Euplea")	Shallow	Delle Chiaje, 1829	0
1983	**A**	Ischia -Punta Caruso	18 m	Herbarium SZN (other collections): 2.6.1983	1
1985	**D**	Bagno delle Sirene/Ninfeo antico Sorrento x 5 foto	1 m	*CiSci Photo: Gargiulo E.(1985)*	0
1990-2000	**D**	Banco di S. Croce	about 20 m	*CiSci Photo: Gargiulo E.*	0

T20. *Sargassum* sp.

Year	Sector	Site	Depth	Reference	CR	CI
1927	**B**	Nisida lato nord	Shallow	Funk, 1927	0	
1954	**B**	Banco di Miseno	Deep	Parenzan, 1956	0	
1959	**D**	Costa Sorrentina	2-4 m	Ernst, 1959	0	
1961	**C**	Capo Posillipo	n.d.	Herbarium SZN (other collections): 12.12.1961	0	

1962	**B**	Miseno	2 m	Herbarium SZN (other collections): 2-11.6.1962	0	
1963	**C**	Capo Posillipo	n.d.	Herbarium SZN (other collections): 15.5.1963; 12.12.1961	0	
1963	**C**	Gaiola	12 m	Herbarium SZN (other collections): 21.1.1963	0	
1963	**C**	Santa Lucia	1-2 m	Herbarium SZN (other collections): 26.6.1963	0	
1965	**B**	Nisida - Porto Paone	0.5-1.5 m	Gamulin-Brida, 1965	0	
1985	**D**	Marina Grande di Sorrento	Shallow	*MAP CiSci project: Gargiulo E. & R. map and photo*	0	
1985	**D**	Pta gradelle - Capo a dx di Sorrento	Shallow	*MAP CiSci project: Gargiulo E. & R. map and photo*	1	SV
1985	**D**	Punta del Capo	>5 m	*CiSci Photo: Gargiulo E.(1985)*	0	
1999	**C**	S. Croce Bank	n.d.	Bussotti et al., 1999	0	
2000	**C**	Rendell Harbour	0 m	Simeone (pers. comm.)	0	
2001	**E**	Faraglione Matermania	2-15 m	Ribera d'Alcalà & Russo, 2001	0	
2001	**E**	Punta di Mulo	0.5 m	Ribera d'Alcalà & Russo, 2001	0	
1909-1959	**C**	Posillipo - Punta Cinita	6-8 m	Funk Diary	0	
1965	**C**	Trentaremi	n.d.	Herbarium SZN (other collections): 16.4.1962	1	SV

Annex II - Detailed list of shallow Fucales recorded in 2013-2016 per each sector with the indication of sites and localities

GENUS	SPECIES	SECTOR	SITE
Cystoseira	*amentacea*	A	Castello Aragonese (S, E); Rocce di Sant'Anna; Punta del Bordo-San Pancrazio; Scarrupata; Capo Grosso, Maronti (E), Sant'Angelo (jetty E, W), Cava Grado, Baia del Chiarito, Capo Negro, Punta del Pilaro, Chianare di Spadera, Scannella, Punta dello Schiavo- Scarrupa, La Nave, Punta Imperatore, Pietra Bianca, Pietra Nera, Pietre del Cavallone, Scogli Lorio, Soccorso (N), Scogli Camerata, Forio (jetty W), La Sciavica, Punta Caruso, Punta Cornacchia, Punta Spaccarello, San Montano, Punta di Monte Vico, Punta Sant' Angelo, Punta della Lingua, Punta di Pioppeto, Capo Bove, Punta Ottimo, Punta Serra.
		B	Capo Miseno, Punta Pennata, Punta del Poggio-Bacoli, Punta Le Cento Camerelle, Baia (Castello), Pozzuoli (E)
		C	Porto Paone, Baia di Trentaremi, Conventino, Marechiaro, Posillipo, Capo Posillipo, Sud Italia, Rocce Verdi, Palazzo Manzi, Cinito.
		D	Punta Gradelle, Punta di Sorrento, Solara, Punta del Capo (W), Sea Club Conca Azzurra-Capo Nastro, Marina della Lobra, Baia di Punta Lagno, Marina della Lobra (S), Punta San Lorenzo (S), Le Fontane, Punta Baccoli, Baia di Mitigliano, Fossa Papa, Punta Campanella.
		E	Punta Vivara - Punta Sbruffo, Grotta dell'Arcera, Punta Capocchia, Rio Latino - Cala di Mezzo, Punta del Pino, Cala del Limmo, Capo Ruglio - Punta Carena, Punta del Tuono, Punta Orticella - Scoglio di Marcellino, Scoglio di Marcellino, Scoglio delle Sirene, Grotta del Moschino-Grotta

		dei Preti, Scoglio Longa di Basso, Scoglio Longa di Sopra, Punta del Capo, Scoglio della Ricotta, Grotta della Ricotta.
Cystoseira brachycarpa	A	Scannella (pool), Pietra Bianca, Pietra Nera, Citara, S. Angelo W (Little Bay).
	D	Fossa Papa
	E	Punta dell'Arcera, Scoglio delle Sirene, Scoglio Longa di Basso, Scoglio Longa di Sopra, Punta del Capo.
Cystoseira compressa var. compressa	**A**	Punta Molino, Castello Aragonese (jetty N), Rocce di Sant'Anna, Punta dell'Ardicola, Punta del Tuono, Punta Pisciazza, Punta del Lume, Punta del Bordo, Punta del Bordo- San Pancrazio, Scarrupata, Capo Grosso, Maronti (E); Sant'Angelo (jetty, E , S,W), Cava Grado, Baia del Chiarito, Punta Chiarito, Capo Negro, Punta del Pilaro, Chianare di Spadera, Scannella, Punta dello Schiavo-Scarrupa, La Nave, Punta Imperatore, Citara, Pietra Bianca, Pietre del Cavallone, Pietre Rosse, Cava dell'Isola, Scogli Lorio, Punta del Soccorso (N), Scogli Camerata, Forio Harbour, San Francesco, La Sciavica, Punta Caruso, Zaro, Punta Cornacchia, Punta Spaccarello, San Montano (E,W), Grotta del Mago, Punta di Monte Vico, Spiaggia delle Monache, Punta dell'Alaca, Punta di Mezzogiorno, Vivara (harbour), Punta della Palombara, Chiaiolella, Punta Solchiaro, Seno del Carbonchio, Punta Pizzaco, Punta dei Monaci, Punta Sant'Angelo, Punta della Lingua, Punta di Pioppeto, Capo Bove, Punta Ottimo, Punta Serra.
	B	Lo schiavone-Miliscola (W), Capo Miseno, Punta Terone, Punta Pennata, Baia (Castello), Punta Epitaffio, Pozzuoli La Pietra,
	C	Porto Paone, Nisida, (E) Baia di Trentaremi, Grotte di Trentaremi, Isola di Gaiola, Conventino; Marechiaro, Posillipo, Sud Italia, Rocce Verdi.
	D	Bikini beach club, Scoglio Fusarella, Punta Gardelle, Vico Equense - Marina di Equa, Punta di Sorrento, Solara, Punta del Capo, Punta del Capo (W), Sea Club Conca Azzurra-Capo Nastro, Marina della Lobra, Le

		Fontane, Punta Baccoli, Baia di Mitigliano, Fossa Papa, Fossa Papa (N), Punta Campanella (East).
	E	Marina Grande (E), Punta Vivara - Punta Sbruffo, Punta dell'Arcera, Punta di Vetereto, Punta del Miglio, Punta Orticella - Scoglio di Marcellino, Punta Campetiello - Cala del Rio, Rio Latino - Cala di Mezzo, capo Ruglio - Punta Carena, Punta Carena, Ardicolella, Punta dell'Ardicola, Punta del Tuono, Punta Orticella - Scoglio di Marcellino, Scoglio di Marcellino - Scoglio delle Sirene, Scoglio delle Sirene, Marina Piccola - Scoglio Unghia Marina, Grotta Albergo dei Marinai, Porto di Tragara, Grotta del Moschino-Grotta dei Preti, Punta del Capo, Scoglio della Ricotta, Grotta della Ricotta, Punta del Fucile, Punta Caterola
Cystoseira compressa* var. *pustulata	**A**	Punta Imperatore (pool), Scannella (pool), Zaro (pool).
Cystoseira crinita	**A**	Cava Grado (E), Chianare di Spadera, Scannella (pool), Punta Imperatore
Cystoseira foeniculacea	**A**	Zaro (pool)
	D	Regina Giovanna-Punta del Capo (pool)
Cystoseira foeniculacea* f. *foeniculacea	**A**	Pietra Nera, Zaro
	D	Regina Giovanna
Cystoseira foeniculacea* f. *latiramosa	**D**	Mitigliano Bay
Cystoseira mediterranea	**A**	Sant'Angelo, Punta Imperatore, Punta S. Pacrazio, Scannella, Zaro, Camerate, Rocce di S. Anna
	B	Il Poggio
	E	Marina Grande (W)

Sargassum vulgare	**A**	Punta Molino, Castello Aragonese (jetty N and S), Rocce di Sant' Anna, Punta San Pancrazio, Baia San Pancrazio, Maronti (E), Sant'Angelo (W), Scannella (pool), Punta Imperatore, Zaro, Spiaggia delle Monache, Zaro (pool).
	B	Miseno, Punta Pennata, Punta del Poggio-Bacoli, Arco Felice, Pozzuoli (E) , Pozzuoli via Napoli, Pozzuoli La Pietra
	C	Baia di Trentaremi, Rocce Verdi
	D	Punta Gradelle, Vico Equense - Marina di Equa

The cover pictures of the chapters of this thesis are by the author,
except for:

Chapter 1 (Mikel Zabala & Jordi Corbera)
Chapter 3 (Composition of photo by: Delizia, 2004; Solntsev, 1840; http://www.blog.blomming.com/; http://www.guidaischiashopping.it/ristorante-ricciulillo/)
Chapter 7 (Enrico Gargiulo)

All the other photos included in this thesis (except some old anonymous picture testyfing the historical neapolitan landscape) are made by the author